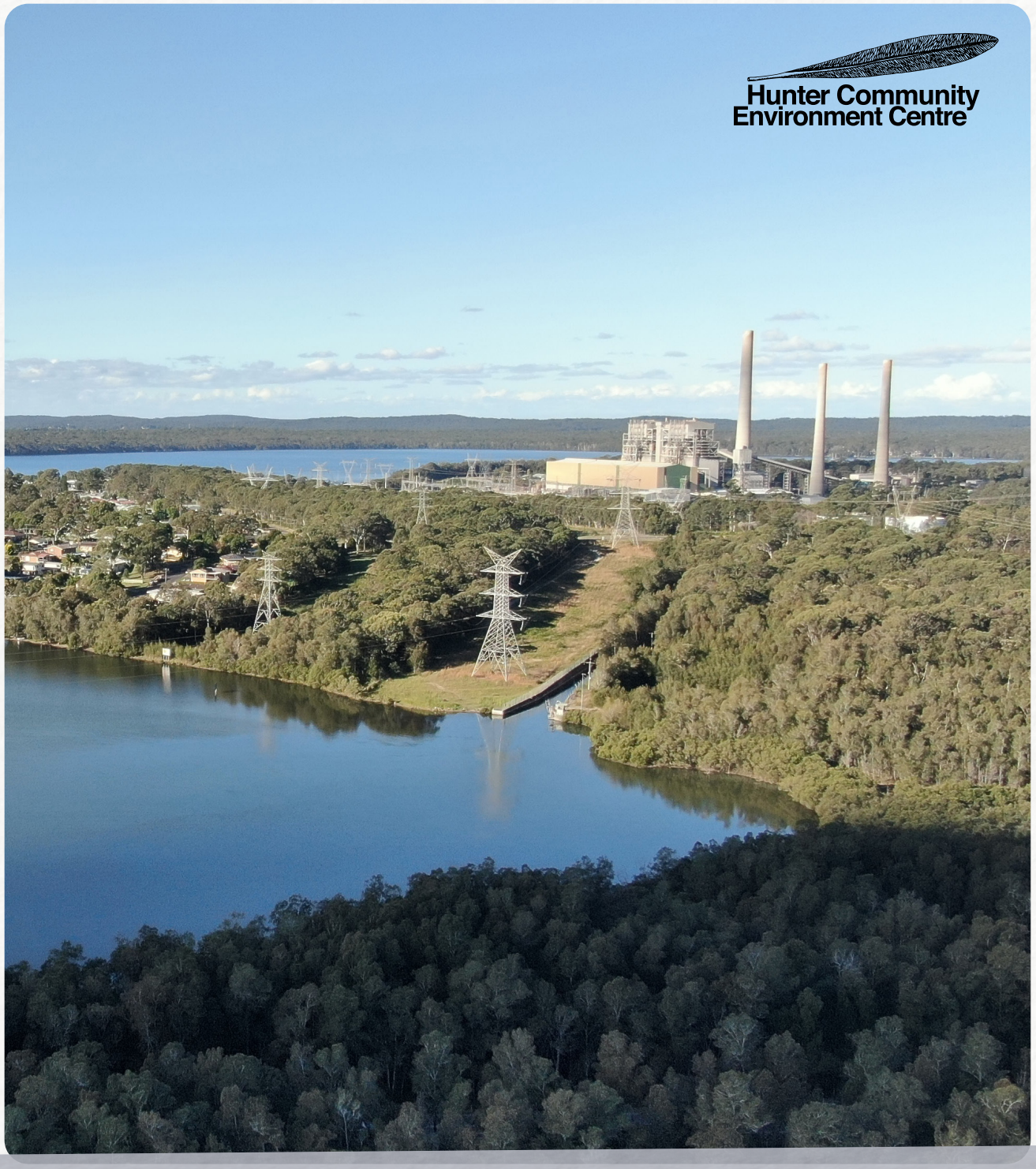

Hunter Community Environment Centre

Delta's dirty deeds done dirt cheap:

The impacts of Vales Point Power Station on Lake Macquarie

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HCEC wish to note with gratitude the varied contributions in support of the publication of this report received from: the many participants who volunteered time at our Citizen Science events held in Southern Lake Macquarie to date the team at Environmental Justice Australia and in particular, the support of Ms Jocelyn McGarity the many local grassroots groups and individuals speaking up for the health of the community and the Lake Macquarie estuary

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ABN 40826463714
Publication date: May 6, 2023
ISBN: 978-0-6452693-3-8

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Executive Summary

The Vales Point power station and the mines that supply its coal were built by the NSW Government in 1963 with a second power station built to replace it in 1979. These operations have had an enormous impact on Lake Macquarie. However, since privatisation of the power station in 2015, and the purchase of Chain Valley and Mannering Collieries in 2019, Delta has been in chronic breach of Environmental Protection Licence (EPL) conditions.

Water levels in the 500 ha ash dam have not been managed to effectively minimise or prevent the pollution of groundwater and Lake Macquarie, and plant and equipment have not been maintained in a proper and efficient condition so as to minimise impacts. The power station and coal mining operations Delta owns have been responsible for 57 Licence breaches relating to the pollution of Lake Macquarie, as well as for two breaches for asbestos dumping, and two for potentially toxic coal ash blowing onto neighbours.

Delta seems to believe it is immune from prosecution, and continues to pursue profit over compliance with the laws of NSW. The Environmental Protection Authority (EPA), tasked with protecting the surrounding population and environment from such corporate avarice, has instead relied on Infringement notices and public shaming. However, these processes have not been effective in addressing the continual degradation of Lake Macquarie.

The Vales Point power station pumps twice the equivalent volume of Lake Macquarie every year to cool its condensers. This has been shown to kill large fish and marine turtles at the intake screens, and most or all of fish larvae and plankton taken through the power station, severely reducing the ecological productivity of southern Lake Macquarie.

When cooling water is released back into Wyee Bay it has been treated with chlorine and other chemicals and heated by about 10^{0}C, killing or damaging the seagrass within about two kilometers from the outlet. The power station's thermal pollution has been discharged up to 11.3^{0}C above average ambient Lake temperatures in winter and 15.7^{0}C above ambient temperatures in summer. No power station built anywhere in the world today would be approved to discharge thermal pollution at such temperature differentials.

Elsewhere in the world, power stations are required to limit the temperature differential of discharged cooling water to between 3 and 5^{0}C. However, even after clear evidence of ecological damage to the Lake, and its causes, since 2005 the EPA has approved three temperature increases that has allowed the company to discharge hot water to 38.5^{0}C, so Delta can maximise profits when electricity demand is highest. Evidence suggests summer discharge temperatures remain far too high, and the discharge temperatures in winter have yet to receive any regulatory attention.

Compelling evidence suggests about 55 ha of seagrass has been lost due to Delta's excessive thermal pollution. It is unlikely that seagrass recovery will occur until discharge temperatures in summer and winter are reduced considerably.

Based on DPI Fisheries calculations and data, we estimate Delta's thermal pollution has been responsible for an estimated $12.6M a year in lost commercial fishery production, and over the period 2005 to 2023 commercial fisheries of south eastern Australia suffered an estimated combined loss of about $226.8M.

Compounding the effects of thermal pollution on Lake Macquarie is contamination by nutrients, metals, metalloids, and turbidity from the Vales Point ash dam and coal mines. Numerous reports have shown that the ash dam is a significant source of phosphate, and Delta Electricity and Delta Coal have breached EPL limits for Total Suspended Solids (TSS) almost 50 times since taking ownership. The cumulative impacts of these additional inputs together with the elevated temperatures have never been assessed. However, these inputs are likely to significantly magnify impacts.

The ash dam holds far too much water, which mobilises toxins within the ash. Elsewhere in Australia and the world, coal ash is transported to storage facilities using far less water than used by Vales Point. The installation of new dense phase ash transport infrastructure designed to reduce the water collecting in the ash dam is essential in reducing groundwater contamination, and the continual contamination of Lake Macquarie with metals and metalloids.

Combined with elevated temperatures, nutrients, turbidity, and toxins for which the power station and coal mines are responsible, is the additional risk of up to 1,200kg of chlorine which is added to the power station cooling water each day and discharged into Wyee Bay. Peak chlorine concentrations are well above both National Water Quality Guidelines and levels shown to cause impacts on marine life.

The second mass death of fish in Wyee Bay in September 2022 that sparked an as yet unresolved EPA criminal investigation and the securing of power station equipment, appeared to have be concentrated nearest to the hot water outlet and may well be related to the discharge.

The Vales Point power station and its coal mines have recently been purchased by a new private company who has shown itself to give scant regard to the communities and environment in which it operates in Europe. The new owner has indicated its intention to operate beyond the design life of the power station in 2029.

Much of the pollution from the power station and mines is the result of a desire by the owner to save on the costs of essential maintenance and upgrades. The community and environment of Lake Macquarie are suffering as a result of these cost savings and the new owner must be forced to upgrade the pollution mitigation procedures and machinery. The EPA must also be provided with the will and the funding to ensure these upgrades are made.

Recommendations

1. To encourage the rejuvenation of Zostera seagrass within Wyee Bay, a study be undertaken that determines ambient water quality, appropriate seasonal temperature differentials, seagrass sensitivity, and the assimilative capacity of Wyee Bay, and EPL 761 be varied accordingly to incorporate a scientifically established thermal mixing zone south of Wyee Marina.

2. To offset seagrass loss in Myuna and Wyee Bays, a Lake Macquarie Seagrass Trust be established with funding of $12M a year from Delta Electricity and $8M a year from Origin Energy to enhance seagrass meadows within Lake Macquarie and replace seagrass damaged and killed by the operations of Vales Point and Eraring power stations.

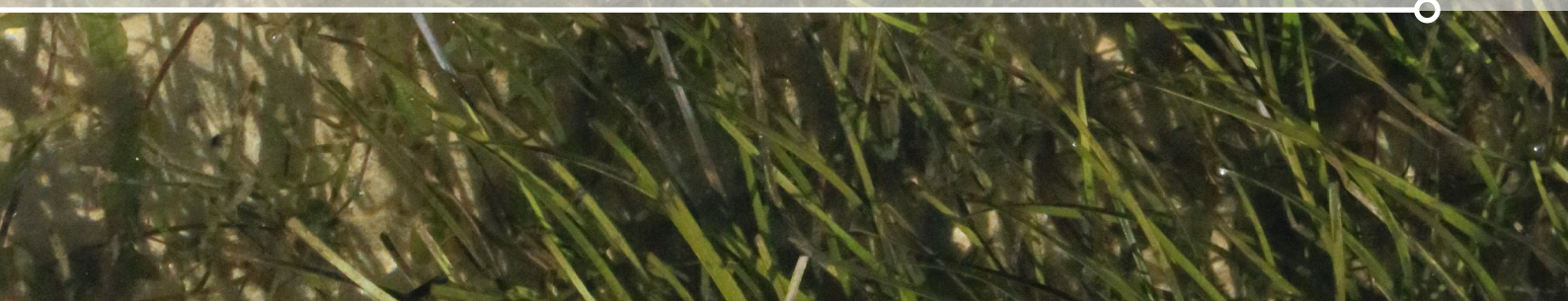
3. A Pollution Reduction Program be established to reduce the amount of chlorine discharged into Wyee Bay, and to force Delta Electricity to upgrade its procedures for reducing biofouling of condensers and pumps.

4. After appropriate trials and engineering design, to minimise toxic trace elements contained within Vales Point coal ash from mobilising and entering groundwater and Lake Macquarie, EPL 761 be varied to incorporate a clause that directs Delta Electricity to install new plant and machinery for dense phase ash transport to the Vales Point Ash Dam.

5. A cumulative impact study be undertaken under a variation to EPL 761, EPL 191 (Mannering Colliery), and EPL 1170 (Chain Valley Colliery) to establish a Pollution Reduction Program for Total Suspended Solids (TSS), faecal coliforms, oil and grease, and metals and metalloids, and to determine the interaction of mine subsidence, the undermining of Vales Point ash dam, and their impacts on marine life in Wyee and Chain Valley Bays.

6. The NSW Environmental Protection Authority (EPA) be adequately funded to ensure appropriate oversight and regulation of large corporate polluters, and enhance its ability to prosecute polluters.

7. The $15,000 the EPA can issue under Penalty Notices be increased to $150,000.



Contents

Introduction

For the past 60 years Vales Point power station has been burning coal to generate electricity. Sitting on the peninsular between Wyee and Chain Valley Bays, at the southernmost end of Lake Macquarie, the current Vales Point B power station (1,320 MW) was fully commissioned in 1979 to replace the Vales Point A power station which was built on the same site in 1963.

The Vales Point site is about 10,070 ha consisting of a 180 ha of power station infrastructure and coal storage, which abuts the township of Mannering Park, an ash dam of about 500 ha, and the balance comprising buffer land of high conservation value coastal woodland and wetland (See Figure 1 and 2).

In 2015, NSW Treasury sold the publically owned Delta Electricity and its Vales Point coal-fired power station to Sunset Power International Pty Ltd for $1 million. With a technical life to 2029, Sunset agreed to maintain the workforce for four years and take on basic decommissioning costs. The NSW Treasurer assured the public at the time that this was to shift the contamination liability to the new owner. However, the State indemnified Sunset for the cost of any future remediation of contamination above that which was identified at the point of sale. Sunset was also provided with the right to hand back operational control and ownership of the power station at any time, after which the State would resume ownership of the site, as well as responsibility for demolition and all decontamination and remediation of the land.[1] Two years on from the sale the facility was valued at $722M. In December last year, the value of the power station was written down to $156 million and Sunset sold the facility to Czech family investment group Sev.en Global Investments who has interests in two Queensland power stations and power stations and coal mines in Europe.

The contamination of sediment in southern Lake Macquarie with metals and metalloids, in particular arsenic, selenium, lead, and cadmium, has been the subject of numerous studies since the power station began operating. However, since the privatization of Vales Point; 11 Environmental Protection License (EPL) breaches have occurred for water pollution and coal ash dust, 2 major fish kills occurred sparking a criminal investigation of Delta by the Environmental Protection Authority, seagrass in Wyee Bay has all but disappeared due to excessive thermal pollution, and metal contamination of off-site groundwater has been identified.

1 *NSW Government submission Public Works Committee Inquiry into costs for remediation of sites containing coal ash repositories February 2020.*

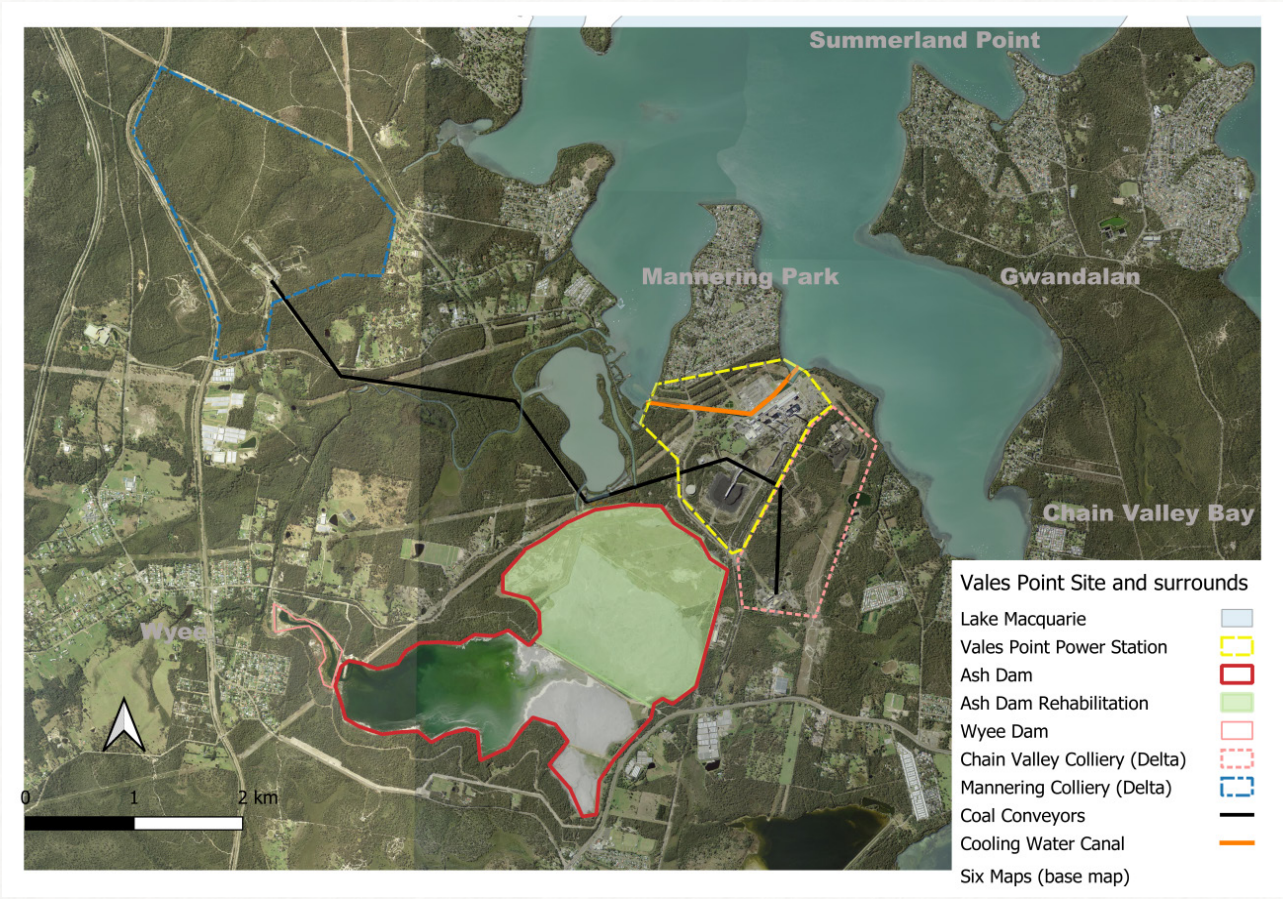


Figure 1: Vales Point power station site and Chain Valley/Mannering collieries, and associated infrastructure

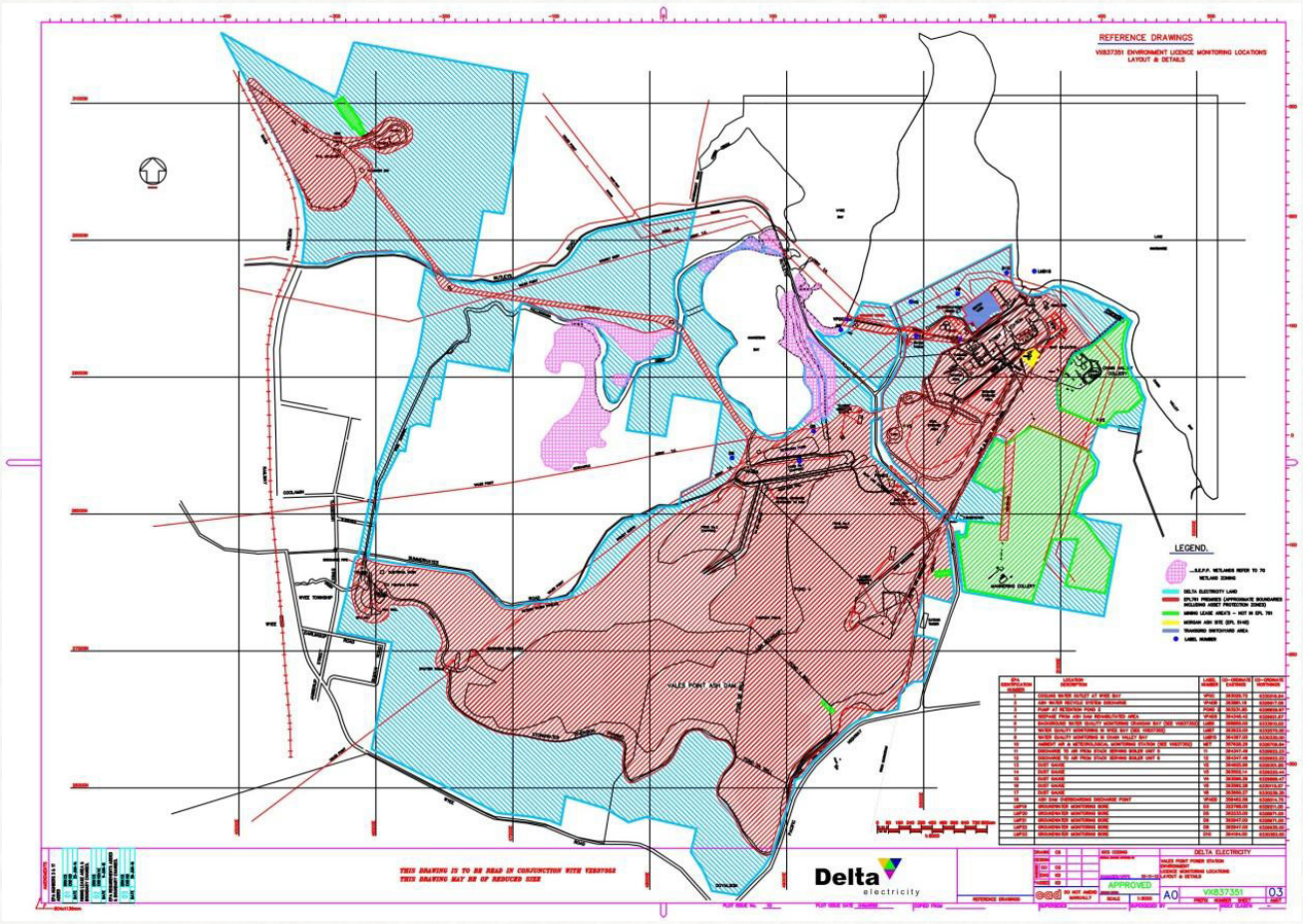


Figure 2: Vales Point power station site and Chain Valley/Mannering collieries and associated infrastructure. Light Blue - Delta Electricity land; Red - EPL 761 Licences Premises; Green - Mining Lease area; Purple - SEPP Wetlands; Dark Blue - Transgrid

The mine that supplies coal to the power station, also owned by the same parent company (Delta Electricity), is also in chronic breach of its EPL conditions. The POEO Register reveals that Delta Coal has only been compliant in six of the past 22 years, with 23 individual breaches since Delta Coal took ownership (2019). Delta Coal's operation is in habitual breach of EPLs with exceedances of discharge volumes, faecal coliform, Total Suspended Solids, and oil and grease concentrations occurring multiple times in some years.

The Lake Macquarie community and the Lake itself have long-suffered as a result of pollution from the power station and associated coal mines. The facilities are old, dirty, and poorly maintained. The expectation has been that the power station and mine would close in 2029, and the clean-up could begin. Indeed, coal mining is currently approved to 2027 and electricity generated by Vales Point is predicted to be in excess of demand once the 500KV transmission line is installed between Eraring and Bayswater, which is expected to be completed by July 2027.[2] Nevertheless, the new owners have indicated their desire to operate beyond 2029, seeing the purchase as a long-term investment opportunity.[3] To continue to operate at a standard expected by the community, several upgrades are required to minimize heavy metal leachate entering the Lake as well as to limit the impacts to aquatic life such as sea grass communities, and fish and crustacean stocks. If the facility is to operate past 2027, when the 500KV transmission line between Eraring's and Bayswater power station is complete, the Vales Point power station must be brought up to the standards expected by the community. This would require amendments of the Environmental Protection Licences (EPL) to force upgrades to coal ash management, cooling water discharge, and air pollution mitigation apparatus.

This report sets out the lingering environmental issues of the power station and mines and identifies best practice management practices recommended to be incorporated into EPL Variations by the Environmental Protection Authority (EPA).

Vales Point cooling water system

To cool the Vales Point power station condensers, salt water from Lake Macquarie is drawn in through a canal on the north western shore of Chain Valley Bay. Once it has cooled the condensers, the heated water runs through an open canal and is returned to the Lake on the eastern shore of the southern-most end and of Wyee Bay. The flow rate is 3,410 ML day with a design temperature rise of 12°C. The magnitude of the elevation in temperature is dependent upon ambient lake (i.e. cooling water intake) temperatures and electricity production.

The maximum discharge volume set out in the Vales Point EPL is 6.5 billion litres each day (GL/day) with a designed maximum discharge temperature of 35°C, which is complied with most of the time (98%). However, since 2005 the maximum discharge temperature of 37.5°C has been allowed for a limited period (2%), and since 2017 up to 38.5°C has been allowed to supply NEM electricity shortfalls. The recorded maximum temperature of the hot water discharged since 2013 has been 38.1 ° C.[4]

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2 *AEMO, 2022. Appendix 5. Network investments. Appendix to the 2022 ISP for the National Electricity Market. A5.4.3 Sydney Ring (Reinforcing Sydney, Newcastle, and Wollongong Supply). https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/a5-network-investments.pdf?la=en*

3 *See for example https://www.abc.net.au/news/2023-03-16/new-vales-point-power-station-owner-wont-commit-to-2029-closure/102105312*

4 *Delta Electricity (Feb, 2017; Sep 2018;Jan 2020; Feb 2020). Environmental Licences and Monitoring. Vales Point Power Station Monthly Environmental Data Summary; Point 22. Discharge of cooling water from the cooling water outlet canal to Wyee Bay. https://www.de.com.au/environment/environmental-licences-and-monitoring?retain=true&PagingModule=877&Pg=1*

Figure 3 Vales Point power station cooling water intake Chain Valley Bay

Figure 4: Vales Point intake

Figure 5: Vales Point hot water outlet in southern Wyee Bay

Figure 6: Vales Point hot water outlet and Wyee Bay

Wyee Bay, which receives the hot water discharge is 17km^2 in area and has an average depth of 1.47 m.[5] An equivalent volume to almost twice that of Wyee Bay (2,514 ML) can be discharged via the power station discharge canal every day leading to a thermal plume which extends a considerable distance from the Bay. The southern end of Wyee Bay also receives discharges from Wyee Creek and Mannering Bay which lie downstream of the power station's ash dam. Sediments of Wyee Bay are contaminated in heavy metals, such as selenium[6] and have been associated with elevated metal levels found in benthic infauna.[7]

Climate Change

The 2020 Lake Macquarie State of the Environment Report[8] identifies climate-induced water temperature in Lake Macquarie is rising at about the same rate as ocean warming from 1970–2010 (0.015°C per year). Water temperature is likely to continue to rise at the same rate as oceans, ultimately having implications for some less tolerant species (such as seagrass) but also facilitating more heat tolerant tropical species (such as marine turtles). Lakes in NSW are also acidifying at the rate of about 0.5 pH units each decade. Acidification of NSW estuaries will continue but retention and enhancement of seagrass and other marine vegetation will provide a critical buffer against acidification.

A 2020 report on the State and Trends of Australia's ocean suggested that the temperature of ocean waters of temperate eastern Australia has increased by 0.5°C since Vales Point was commissioned. [9]
The Bureau of Meteorology's State of the Climate 2022 identifies that 2016 had the highest sea surface temperature ever recorded, associated with one of the strongest negative Indian Ocean Dipole events on record and the 2015–16 extreme El Niño event.

Since 1970, the greatest ocean warming has occurred off south-east Australia and Tasmania, with the East Australian Current extending further south, creating an area of rapid warming in the Tasman Sea, where the warming rate is now twice the global average. [10] The increasing frequency of marine heatwaves around Australia in recent years has permanently impacted marine ecosystem health, marine habitats and species. These impacts include depleting kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease. [11]

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5 *Ingleton, Timothy & McMinn, Andrew. (2012). Thermal plume effects: A multi-disciplinary approach for assessing effects of thermal pollution on estuaries using benthic diatoms and satellite imagery. Estuarine, Coastal and Shelf Science. 99. 132-144. 10.1016/j.ecss.2011.12.024.*

6 *Roach AC. 2005. Assessment of metals in sediments from Lake Macquarie, New South Wales, Australia, using normalisation models and sediment quality guidelines. Mar Environ Res. 2005 Jun;59(5):453-72. doi: 10.1016/j.marenvres.2004.07.002. PMID: 15603769.*

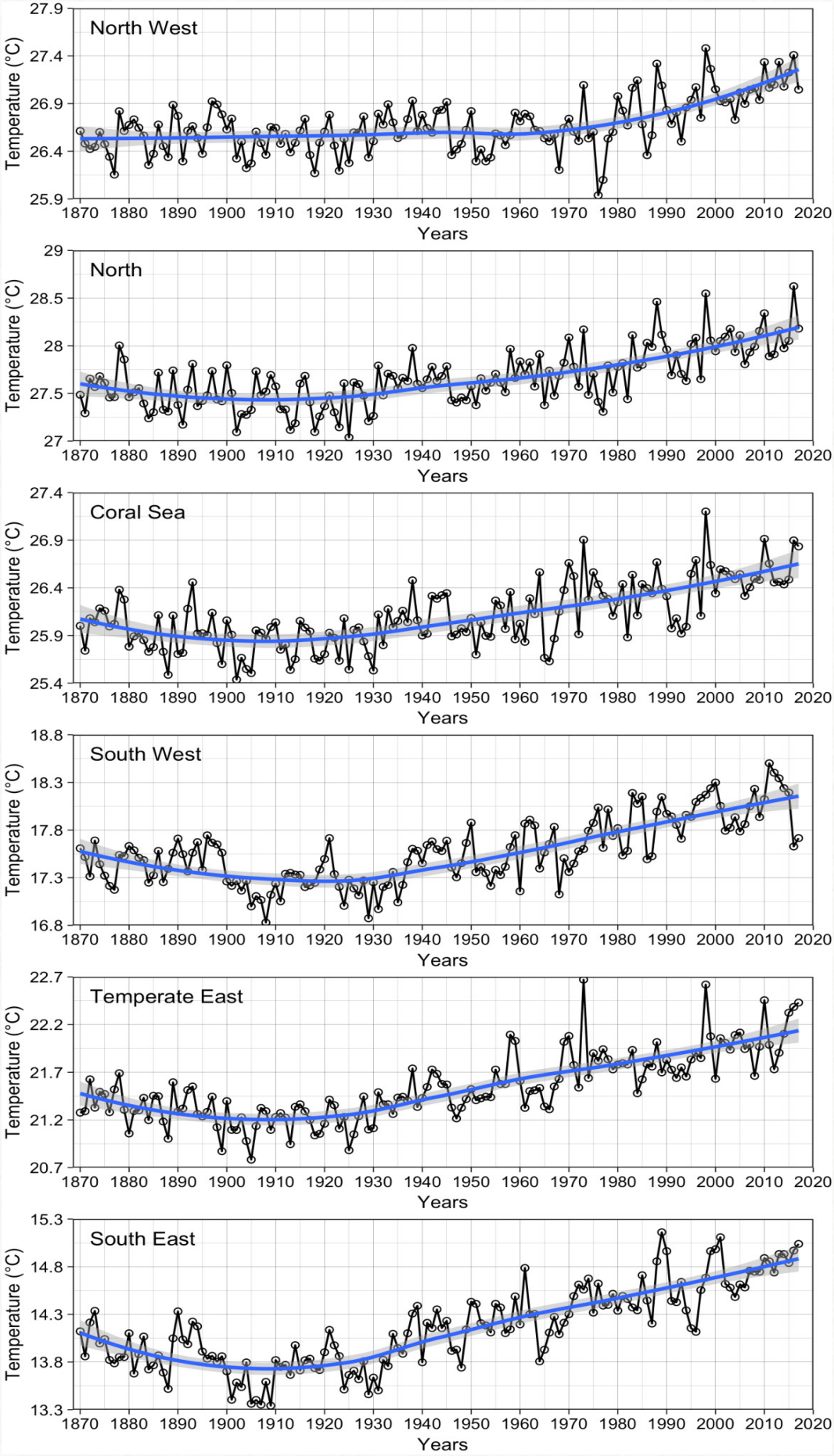
7 *Peters, G. M., Maher, W. A., Krikowa, F., Roach, A. C., Jeswani, H. K., Barford, J. P., Gomes, V. G., & Reible, D. D. (1999). Selenium in sediments, pore waters and benthic infauna of Lake Macquarie, New South Wales, Australia. Marine Environmental Research, 47(5), 491-508. https://doi.org/10.1016/S0141-1136(99)00027-6*

8 *Department Of Planning, Industry & Environment, 2020. State of the Estuary Lake Macquarie 2020 . https://shape.lakemac.com.au/51665/widgets/270428/documents/207502*

9 *Richardson AJ, Eriksen R, Moltmann T, Hodgson-Johnston I, Wallis J.R. (2020). State and Trends of Australia's Ocean Report, Integrated Marine Observing System (IMOS). https://www.imosoceanreport.org.au/about/*

10 *State of the Climate 2022, CSIRO and Bureau of Meteorology, © Government of Australia. http://www.bom.gov.au/state-of-the-climate/oceans.shtml*

11 *State of the Climate 2022, CSIRO and Bureau of Meteorology, © Government of Australia. http://www.bom.gov.au/state-of-the-climate/oceans.shtml*


North West
Temperature (°C)
27.9
27.4
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North
29
28.5
28
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27
Coral Sea
27.4
26.9
26.4
25.9
25.4
South West
18.8
18.3
17.8
17.3
16.8
Temperate East
22.7
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1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
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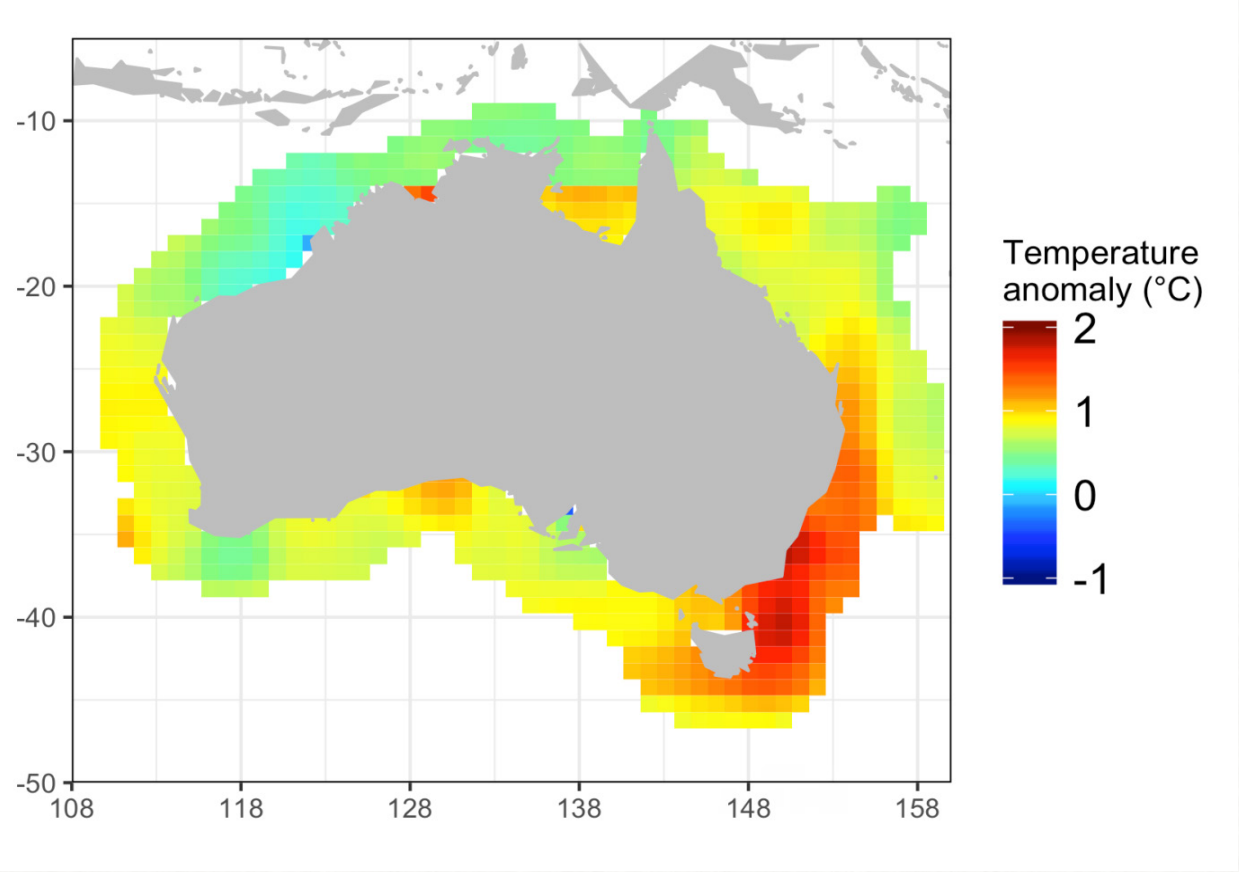

Figues 7 (Top) and 8 (Bottom): Climate induced temperature anomalies for Temperate East (Top) and Australia (bottom). [12]

Climate change has therefore made it incrementally more difficult for the Lake Macquarie power stations to keep under the designed temperature increase of its cooling water.

Chlorine pollution

The environmental impact on estuaries caused by thermal pollution from power stations has been well documented.[13] However, dosing of chorine to remove fouling by sea life can also have significant impacts on estuarine ecosystems.[14]

The Vales Point power station operates a chlorine plant which produces 0.14% sodium hypochlorite, used to treat two auxiliary pumps and two main condenser pumps against fouling by sea life. Delta generates chlorine at the rate of 7.5 litres per second. The auxiliary pumps are dosed continuously at 4.5 litres per second and when the holding tank is full, dosing of the main condensers is undertaken at 14-15 litres per second (mixed with intake water) for 2 hours each.[15]

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12 *Copied from Richardson et al (2020) Op cit*

13 *Bamber R.N. (1995) The influence of rising background temperature on the effects of marine thermal effluents. J. Therm. Biol. 20 105-110.*

14 *W. L. T. van Densen & R. H. Hadderingh, 1982. Effects of entrapment and cooling water discharge by the Bergum Power Station on 0+ fish in the Bergumermeer. Hydrobiologia 95, 351-368. https://link.springer.com/article/10.1007/BF00044495#citeas*

15 *HLA Envirosciences, 2007. Conceptual Model of Vales Point Power Station Cooling Water System for: Delta Electricity Vales Point Power Station. Accessed under GIPA Act, EPA860*

Residual chlorine concentrations in the condensers are estimated to be 0.4-0.5 mg/L during dosing, and 1.2-1.6 mg/L at the condenser outlet, not considering the effects of heat dissipation, turbulence and salinity. The discharge from the main condensers occurs daily.[16]

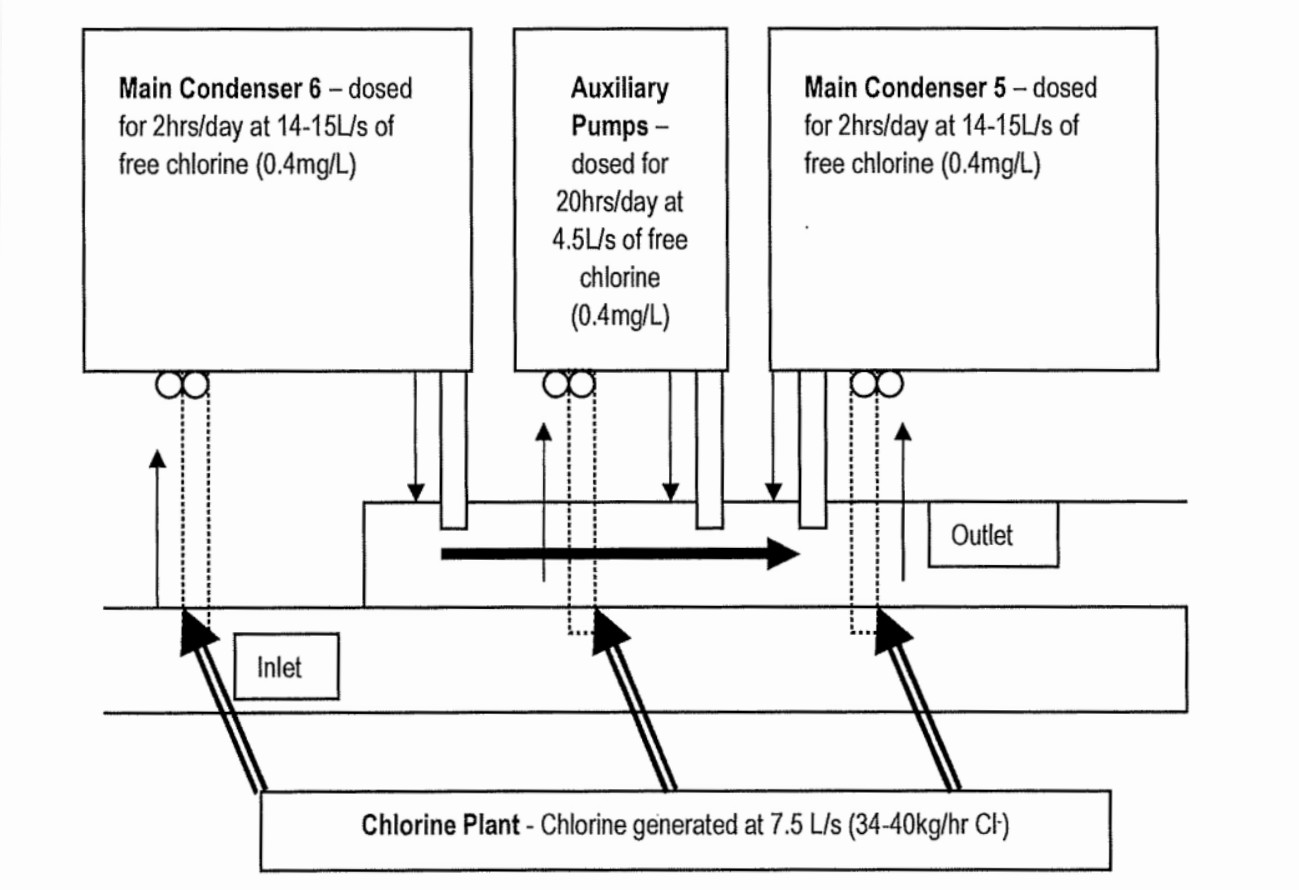

figure 9. Chlorine dosing process[17]

A 2007 ecotoxicology report commissioned by Delta Electricity[18] concluded that fish larvae were sensitive to chlorine at 0.1mg/L and sea urchin fertility was affected at less than 0.04 mg/L, and determined a No Observed Effect Criteria for three of the species tested (50%) was below the detection limit of chlorine (0.04mg/L). The peak free chlorine concentration at the hot water discharge outlet was found to be between between two and three times this concentration (0.08 and 0.12 mg/L).

An internal DECC summary[19] of the toxicity report identified the relationship between toxicity and temperature, which the Vales Point Toxicity Report failed to incorporate. The Summary suggested that "...temperature can affect chemical toxicity by altering the physiological condition of the biota and the interaction between organisms and toxicants. Temperature alone directly or indirectly impacts the distribution of aquatic organisms and their physiological processes. As temperature is a critical factor affecting the toxicity of chemicals in the aquatic environment it would be more realistic to conduct toxicity test simultaneously under several temperature regimes (on the basis of the results of the temperature tolerance tests)".

Indeed a report for Eraring Energy found the elevated temperature that killed or severely impacted 50% of the test population (LT50 or ET50) were between 27.5°C (mussel) and 32.2°C (polychaet worms), with fish and diatom below 28°C. These figures provide

16 *Ecotox, 2007. Assessment of Temperature Tolerance and Toxicity Assessment Chlorine in Vales Point Power Station Discharge Delta Electricity Test Report August 2007. Accessed via GIPA EPA860.*
17 *Ecotox, 2007. Assessment of Temperature Tolerance and Toxicity Assessment Chlorine in Vales Point Power Station Discharge Delta Electricity Test Report August 2007. Accessed via GIPA EPA860.*
18 *Delta Electricity, 2007. Assessment of Changes in Wyee Bay Seagrass Percent Cover in 2007 Relative to 1980 to 2007 Distribution Changes Delta Electricity 17 September 2007*
19 *DECC, 2008. Assessment of temperature tolerance and toxicity assessment of chlorine in Vales Point Power Station discharge. Accessed under GIPA Act EPA 860*

basic temperature tolerance figures for these species which should be considered when analysing the temperature effects of the effluent.[20] The figures are well below the general EPL maximum hot water discharge temperatures of 35°C.

The Summary identified the ANZECC & ARMCANZ water quality guidelines recommend a freshwater trigger value for chlorine of 0.003 mg/L. The figures obtained in the Toxicity Report suggested a No Observed Effect Criteria (NOEC) for the protection of 95% of marine species was estimate at 0.0009 and 0.0012 mg/L, which "indicates the potential sensitivity of the marine environment to chlorine. If sensitivity to temperature is added to this, the effluent could pose localized issues for sensitive species". No data on actual or potential temperature and chlorine levels of the effluent was included in the 2007 ecotoxicology Report.

Delta's EPL allows 1200kg of chlorine to be added to the cooling water system each day and limits the concentration of free chlorine at the hot water discharge point at 0.2 mg/L, over 200 times the NOEC for 95% of species tested. For compliance purposes Delta reports just one sample a month. While chlorine concentrations are generally below 0.2 mg/L, they are regularly found between 0.1 and 0.2ug/L, well above the concentration found to effect fish larvae. There appears to be a regulatory disconnect between the chlorine treatment used by Delta (1.2 – 1.6 mg/L at main condenser 5 outlet), the free chlorine concentration limit discharge into Wyee Bay (0.2 mg/L), and the chlorine concentration limit that would protect marine species (0.0009 to 0.0012 mg/L), which appears to be substantially under laboratory detection limits (<0.04 mg/L).

Despite peak chlorine concentrations at the hot water outlet generally remaining under 0.12mg/L, during cooler ambient Lake temperatures many species of fish and other marine life are attracted to the hot water and travel up the cooling water channel. This presents a significant risk to marine life as chlorine concentrations increase towards the power station condenser outlet, which is 60 to 80 times the concentration at the hot water outlet. Indeed, the second mass death of fish in Wyee Bay in September 2022 sparking an EPA criminal investigation and Vales Point power station equipment being secured, appeared to HCEC staff and Mannering Park residents to be concentrated nearest to the hot water outlet. As no temperature anomaly was evident, as was the case with the August 2022 fish kill, it appeared to many that the fish kill had something to do with the cooling water channel.

Impingement and entrainment of marine life

The Vales Point cooling water intake at Chain Valley Bay incorporates a screening system to prevent debris and marine organisms such as seagrass, fish, turtles, driftwood and crustaceans entering the cooling system and power generation units. [21]

Lake water intake first passes through vertical bars known as the trash bars, which act as an initial screen to prevent large debris progressing further into the system. The water is then drawn through an array of self-cleaning rotating screens which collects and removes large marine organisms and debris, which are then washed off the screens into a small slide adjacent to each screen. The slide connects to a channel connecting to a return pipe that takes to the marine organisms and debris to the outlet canal. [22] The capture (impingement) and transportation (entrainment) of marine organisms, such as sea turtles and fish in the screens and intakes of once through cooling water system has a significant impact on the productivity of Lake Macquarie Organisms taken into the cooling water screens can sustain injury or death by entering intakes with the cooling water flow and making physical

20 *Internal DECC email sent, 17 January 2008 RE: Ecotox Assistance - Thermal impacts of power station cooling water on Lake Macquarie. Accessed under GIPA Act EPA 869.*

21 *HLA Envirosciences, 2007. Conceptual Model of Vales Point Power Station Cooling Water System for: Delta Electricity Vales Point Power Station. Accessed under GIPA Act, EPA860*

22 *HLA Envirosciences, 2007. Conceptual Model of Vales Point Power Station Cooling Water System for: Delta Electricity Vales Point Power Station. Accessed under GIPA Act, EPA860*

contact with screens.[23] Water that passes through the screens hold small fish, fish eggs and larvae, and other microscopic organisms that pass through the screens and through the cooling system to be discharged with the hit water. [24] These will likely die through physical contact, rapid pressure and temperature change, and chemical poisoning from chlorine and other chemicals introduced into the water.[25]

A report for the 2008 EIS for Eraring's capacity upgrade found that in a 12-hour period in August 2006, 135 fish, crabs and molluscs (squid, cuttlefish, octopus, and prawns) from 26 species were caught in the screens.[26] Ninety three per cent of the fish retrieved were alive, however 28% were damaged. Damage included loss of spines, scales, skin and or fins and swim bladder damage.

This equates to almost 100,000 fish caught each year in Eraring's cooling water intake screens, of which almost 26,000 fish would be damaged (26%), and 7,000 fish killed (7%). Of the 26 species recorded, dead or damaged individuals were recorded for 19 species. Three-bar porcupinefish, silver bellies, stripey catfish, fan-belly leatherjackets, glassfish, herrings and eastern striped trumpeters were particularly affected. Other species affected included batfish, common catfish, garfish, octopus, squid and tailor. However, data for the entrainment study was undertaken in August which is considered to be a period of lower fish activity than the spring and summer months when a greater number of fish would have been caught by the screens.[27]

The number of fish killed or damaged by Eraring has been estimated by NSW Fisheries to be over 25 percent of the fish caught in Lake Macquarie by recreational fishers each year. DPI Fisheries submission to the Capacity Upgrade of Eraring power station in 2008 stated:

- the station currently pumps about three times the entire volume of Lake Macquarie annually.
- entrainment of larval species is of concern as there is a significantly high number of larval fish and prawns that are entrained in the cooling water flows.
- concern also exists in relation to the long term impact of the higher temperatures generated in the discharge water and the modelled impact on the seagrass beds;
- concern exists about the potential long term impact of higher water temperatures in the long term with potential climate change implications of higher temperatures, increased power demands and increasing lake water temperatures;
- DPI recommends that a habitat offset program to offset potential seagrass loss should be developed and implemented.

While no such studies have been undertaken for Vales Point, similar issues are expected. Taken together, Lake Macquarie power stations would be expected to pump about 5 times the entire volume of Lake Macquarie annually. Indeed, given the separation of Lake waters by Wangi Point (see Figure 10 below), it would be more accurate to equate the Lake power stations as pumping about 10 times the volume of southern Lake Macquarie. As most, if not all, the fish and crustacean larvae and plankton taken in through the power station cooling water system would be killed by chlorine, temperature and pressure, the Vales Point power station would significantly decrease the ecological productivity of southern Lake Macquarie.

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23 *Richard M. H. Seaby and Peter A. Henderson, 2007. Entrainment, impingement and Thermal impacts at Indian Point Nuclear Power Station. Pisces Conservation Ltd, November 2007. https://www.riverkeeper.org/wp-content/uploads/2010/03/1397-PH-Henderson-Attachment-3-Expert-Report-Cont-EC-1.pdf*

24 *ibid*

25 *ibid*

26 *HLA-Envirosciences, 2007. Screening and Entrainment Assessment Proposed Capacity Increase and Attemperation Reservoir. 23 March 2007.*

27 *NSW Department of Planning (2008). Major Project Assessment: Eraring Power Station Capacity Upgradeand Attemperation Reservoir, Eraring Director-General's Environmental Assessment Report. Department of Primary Industries (DPI) Submission Summary.*

Thermal pollution

Thermal pollution is defined as the degradation of water quality by any process that changes ambient water temperature.[28] A common cause of thermal pollution is the use of water as a coolant by coal-fired power plants.[29] [30]

In a once through cooled power station, such as Eraring and Vales Point, water is boiled to produce steam and Lake water is drawn in to cool the steam and convert it back to a liquid to be used to produce more steam. [31] Consequently, Vales Point power station was designed to increase the temperature of its Lake Macquarie cooling water by 10^{0} C.

The use of once-through cooling systems has significant impacts on ecosystems due primarily to the lower dissolved oxygen concentration in the warmer water.[32] For example, at 15°C, dissolved oxygen concentration (~10mg/L) is double that of water at 25°C (~5mg/L).[33] High temperature differences between the heated discharge water and the waters receiving the hot water discharge can kill seagrass and fish,[34] and has been shown to increase the rates and size of algal blooms and disease outbreaks. [35]

Even small changes in temperature can induce substantial changes in the biological organization of aquatic ecosystems.[36]Adding heat to an ecosystem has been shown to reduce habitat and change natural processes and have broad consequences for microbes, plants, and animals. [37] Sensitive species are affected first, but these affects are compounded as these diminished food species have impacts on species that dependent on them as principal or exclusive food sources. [38]

The raised water temperature can alter the biodiversity of an ecosystem in two ways.

1. The increased temperature may not be tolerable for aquatic species and/or the increased temperature increases microbial growth, which in turn decreases dissolved oxygen, and
2. It makes metals more bioavailable, or in other ways increases the harm from nutrients and toxins. [39]

The direct effects of thermal pollution include:

- reduction in dissolved oxygen
- lethal and sub-lethal responses of organisms to the change in temperature regime;
- stimulation in productivity of organisms such as algae resulting in increased respiration rates.
- change to the temperature regime of the water column and, in some cases, the sediment.[40]

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28 *Edinger, J.E.; Geyer, J.C. 2015. Heat Exchange in the Environment; Edison Electric Institute: New York, NY, USA, 1965. Sustainability 2015, 7 5942; Langford, T.E.L. 1990. Ecological Effects of Thermal Discharges; Elsevier Applied Science Publishers Ltd.: London, UK; New York, NY, USA, 1990. Hogan, M.; Patmore, L.C.; Seidman, H. 1973. Statistical Prediction of Dynamic Thermal Equilibrium Temperatures Using Standard Meteorological Data Bases; Report EPA-660/2-73-003; U.S. Environmental Protection Agency (EPA), Office of Research and Development: Washington, DC, USA, 1973*

29 *Rosen, Marc & Bulucea, Cornelia & Mastorakis, Nikos & C.A, Bulucea & Jeles, Andreea & Brindusa, Constantin. (2015). Evaluating the Thermal Pollution Caused by Wastewaters Discharged from a Chain of Coal-Fired Power Plants along a River. Sustainability. 7. 5920-5943. 10.3390/su7055920.*

30 *Drbal, L.F., Borton, P., Westra, K.L., Erikson, R.B., Eds. 1996. Power Plant Engineering; Black & Veatch Publishing House: New York, NY, USA, 1996. Istrate, M.; Gusa, M. 2000. Impactul Producerii, Transportului si Distributiei Energiei Electrice Asupra Mediulu (Environmental Impact of Electric Energy Generation and Transportation); AGIR Publishing House: Bucharest, Romania, 2000; Langford, T.E.L. 1990. Ecological Effects of Thermal Discharges; Elsevier Applied Science Publishers Ltd.: London, UK; New York, NY, USA, 1990.*

31 *Rosen et al (2015) op cit*

32 *ibid*

33 *See for example https://www.usgs.gov/media/images/temperature-affects-dissolved-oxygen-concentrations*

34 *Electric Power Research Institute (EPRI). 2002. Water & Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next Half Century; Technical Report EPRI; American Public Health Association (APHA); American Water Works Association (AWWA); Water Environment Federation (WEF), 2005. Standard Methods for the Examination of Water & Wastewater: Centennial Edition, 21st ed.; APHA-AWWA-WEF: Washington, DC, USA, 2005; U.S. Department of Energy, 2015. National Energy Technology Laboratory: Pittsburg, PA, USA, : Palaniappan, M.; Gleick, P.H.; Allen, L.; Cohen, M.J.; Christian-Smith, J.; Smith, C., 2014. Clearing the Waters, A Focus on Water Quality Solutions; United Nations Environment Programme & Pacific Institute: Oakland, CA, USA, 2010. Available online: http://www.unep.org/PDF/ Clearing_the_Waters.pdf*

35 *Vallero, D.A., 2019. Chapter 20 -Thermal Pollution. In Waste (Second Edition).Ed: Trevor M. Letcher, Daniel A. Vallero, Academic Press, 2019, Pages 381-404, https://doi.org/10.1016/B978-0-12-815060-3.00020-7.*

36 *ibid*

37 *ibid*

38 *ibid.*

39 *ibid*

40 *Langford, Terry E. 1990. "Ecological Effects of Thermal Discharges". Elsevier Applied Science, London, UK.*

The indirect effects of thermal discharges on the water environment include:

- changes in the distribution, composition and growth rates of communities of fish and macroinvertebrates;
- impacts on the distribution of bird populations reliant on these organisms; and
- altered nutrient and carbon cycling.[41]

The 1996 Estuary Management Study of Lake Macquarie[42] referred to studies undertaken by UNSW (1972)[43], Sidabutar (1992)[44], and Negarestan (1993)[45] which assessed the aquatic ecological impacts of the increased water temperature near the power station hot water discharge points. These studies found:

- Loss of seagrass in the vicinity of hot water outlets;
- Replacement of zostera beds by halophila in Wyee Bay;
- Changes in fish distribution as snapper, squid, tailor, flat-tail mullet, leather jackets, cardinal fish, glassy perchlets, goatfish, and toadfish were all less abundant in the elevated water temperature, while tarwhine, silver biddy, bream and southern butterfish were more abundant.

It is now generally accepted that the initial rise in temperature of the receiving water at the hot water outlet should be less than 5°C in order to avoid impact on aquatic ecosystems.[46]

Indeed, the *Guidelines for Thermal Power Plants* of the International Finance Corporation requires power plants to limit thermal pollution by "no more than 3°C at the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors, and assimilative capacity".[47]

No such scientifically established mixing zone has ever been developed to mitigate the impacts of the thermal pollution from Vales Point power station. The EPL simplistically applies a maximum temperature to the hot water discharged at the outfall. Indeed, in light of the history of temperature limit increases sought by Delta Electricity and approved by the EPA under flexible Licencing conditions, it appeared up until 2021 that there was no real requirement for the power station to minimise its thermal effects on the sea life of Lake Macquarie in any way.

The average ambient temperature of Lake Macquarie varies between 10.7°C in August to 22.4°C in February.[4849] In the last ten years, Vales Point power station has discharged its hot water to a maximum temperature of 32° C[50] in winter and 38.1°C in summer.[51] This is 11.3°C above average ambient Lake temperatures in winter and 15.7°C above average ambient temperatures in summer. We don't believe that any power station built anywhere in the world today would be approved to discharge thermal pollution of such temperature differentials.

A NSW Fisheries seagrass expert confirmed in a 2008 internal report that the operation of thermal power stations in NSW estuaries had resulted in the loss of Zostera seagrass in areas regularly impacted by the thermal plumes.[52]For example, a 50% decline in total area of Zostera in Myuna Bay which was co-incident with the commissioning of Eraring power station, whereas no such decline occurred in the controls over this time.[53]

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41 *Langford, Terry E. 1990. "Ecological Effects of Thermal Discharges". Elsevier Applied Science, London, UK.*

42 *WMB, 1996. Lake Macquarie Estuary Management Study (LMEMS) Volume 2.*

43 *UNSW (1972) Ecology of selected estuafine organisms Data List No. I and No.2. Project 12- 045-16. School of Zoology, University of NSW, Sydney.*

44 *Sidabutar, T (1992). Zooplankton in the cooling field and in the vicinity of Vales Point Power Station in the southem part of Lake Macquarie, M.Sc Thesis - University of New South Wales.*

45 *Negarestan, H (1993). A comparison among benthic macrofauna in tlmee environments around Vales Point Power Station, Lake Macquarie. M. Sc. Thesis - University of New South Wales.*

46 *Laws, E.A. 2000. Aquatic Pollution: An Introductory Text; John Wiley and Sons: New York, NY, USA, 2000; Goel, P.K. 2006.Water Pollution: Causes, Effects and Control; New Age International: New Delhi, India, 2006. Edinger, J.E.; Geyer, J.C. 1965. Heat Exchange in the Environment; Edison Electric Institute: New York, NY, USA; Langford, T.E.L.1990. Ecological Effects of Thermal Discharges; Elsevier Applied Science Publishers Ltd.: London, UK;*

47 *IFC, 2017. Environmental, Health, and Safety Guidelines Thermal Power Plants Draft for Second Public Consultation—May/June 2017*

48 *https://www.watertemperature.net/australia/lake-macquarie.html*

49 *https://www.tideschart.com/Australia/New-South-Wales/Lake-Macquarie-Shire/Water-Temperature/*

50 *Delta Electricity (Jun 2016). Environmental Licences and Monitoring. Vales Point Power Station Monthly Environmental Data Summary; Point 22. Discharge of cooling water from the cooling water outlet canal to Wyee Bay. https://www.de.com.au/environment/environmental-licences-and-monitoring?retain=true&PagingModule=877&Pg=1*

51 *Delta Electricity (Feb, 2017; Sep 2018;Jan 2020; Feb 2020. Environmental Licences and Monitoring. Vales Point Power Station Monthly Environmental Data Summary; Point 22. Discharge of cooling water from the cooling water outlet canal to Wyee Bay. https://www.de.com.au/environment/environmental-licences-and-monitoring?retain=true&PagingModule=877&Pg=1*

52 *NSW Department of Primary Industries, 2008. Email Dr Bob Creese (bob.creese@dpi.nsw.gov.au) to Rebecca Scrivener DECC 22 February 2008 5:05 Re: Connell Wagner seagrass reports - Lake Mac Attachments: NSW DPI comments on Myuna Bay & Wyee Bay seagrass reports by Connell-Wagner. GIPA EPA860. Document 19, p12/18*

53 *NSW Department of Primary Industries, 2008. Email Dr Bob Creese (bob.creese@dpi.nsw.gov.au) to Rebecca Scrivener DECC 22 February*

Lake Macquarie was a poor choice for receiving thermal pollution from power stations. Only about 1% of the Lake's volume exchanges with ocean waters during an average tidal cycle and averaged e-folding time (a measurement of tidal flushing[54]) is estimated at 277 days.[55] However, tidal flushing of the Lake is highly variable. The southern end of the Lake, where Vales Point power station discharges, the e-folding time is as long as 500 days (See Figure 10).

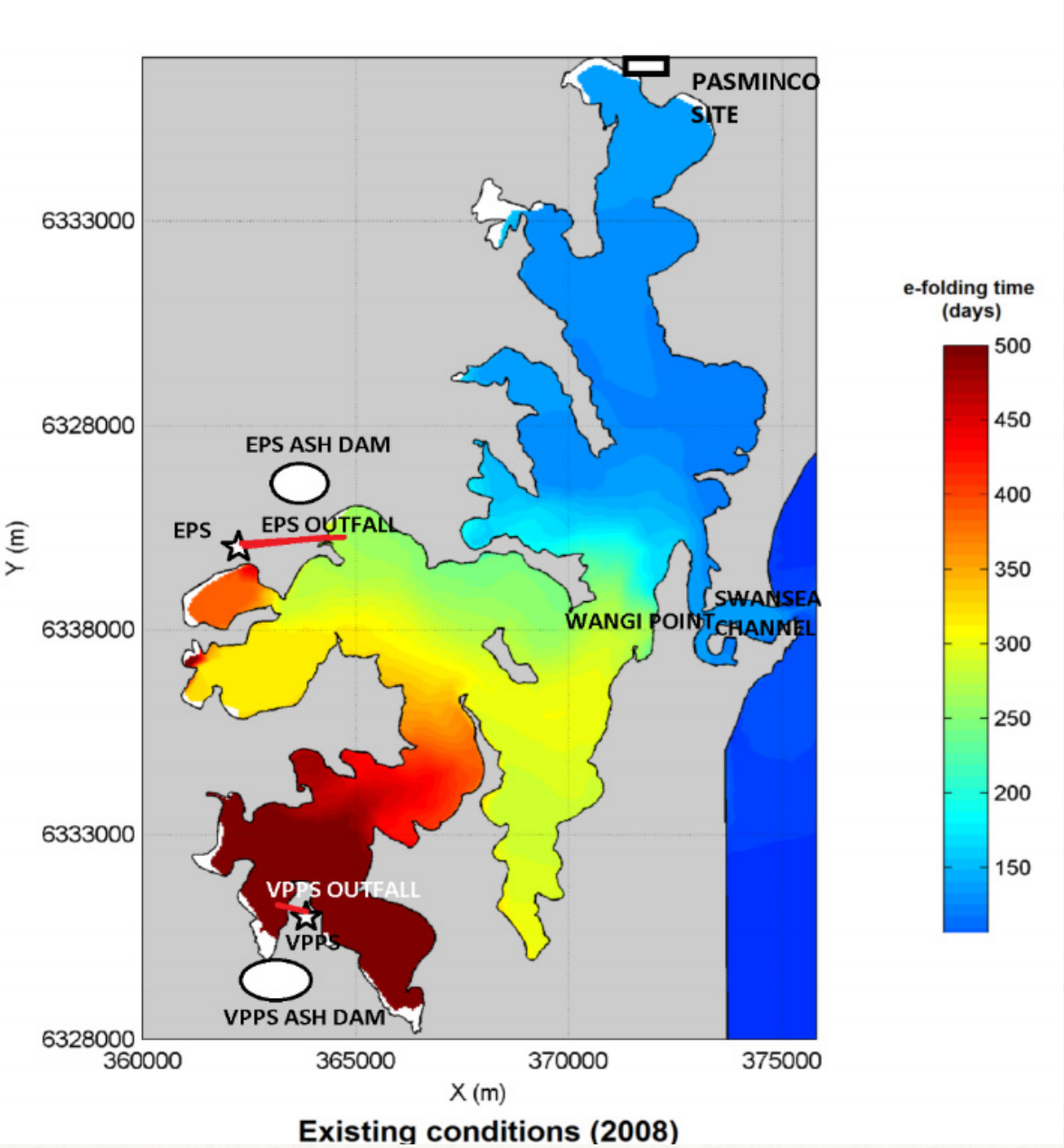

Figure 10: E-folding times in Lake Macquarie.[56]

2008 5:05 Re: Connell Wagner seagrass reports - Lake Mac Attachments: NSW DPI comments on Myuna Bay & Wyee Bay seagrass reports by Connell-Wagner. GIPA EPA860. Document 19, p12/18

54 *Tidal flushing of Lake Macquarie refers to the replacement of water within the lake with water from outside the lake as the tidal fluctuations bring seawater through the channel on the flood tide and carries out lake water on the ebb tide.*

55 *Worley Parsons, 2010a. Tidal Modelling of Lake Macquarie Volume 1. Report for Lake Macquarie City Council*

56 *From Worley Parsons, 2010b. Tidal Modelling of Lake Macquarie Volume 2. Report for Lake Macquarie City Council.*

The furnaces of the aged Vales Point and Eraring power stations were designed for specific coal to be burnt and to operate at base load.[57] Today's competitive electric utility market has required Eraring and Vales Point to cycle their units in-line electricity prices and coal prices and availability.[58] Additionally, replacement of the original design coal with lesser-valued fuels is more common today to reduce operating costs.[59] In the USA, coal-fired power stations have been required to undertake major alterations to power plants in order to maintain the highest plant output and lowest plant heat rate.[60]

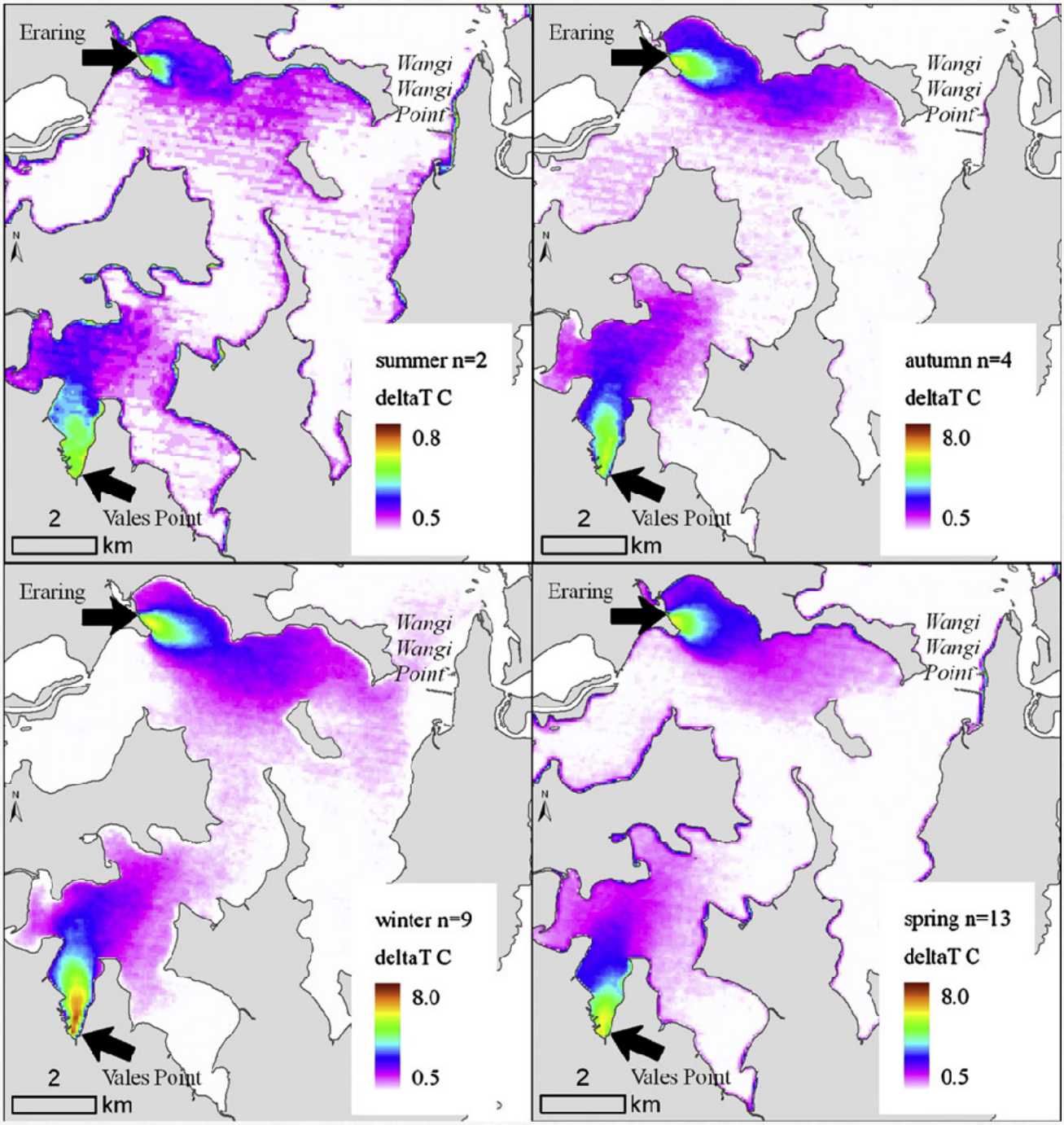

Figure 11.Thermal plume temperatures differentials comparted to ambient Lake Macquarie temperature: seasonal composite 2003 -2008. Copied from Ingleton & McMinn (2012).

57 Sargent & Lundy, 2009. Coal-Fired Power Plant Heat Rate Reductions SI-009597 Final Report January 22, 2009. https://www.epa.gov/sites/production/files/2015-08/documents/coalfired.pdf

58 ibid

59 ibid

60 Kitto, Jr., J. B., S. A. Bryk, J. M. Piepho, 1998. "Upgrades and Enhancements for Competitive Coal-Fired Boiler Systems," Babcock & Wilcox, Technical Paper; National Coal Council, Increasing Electricity Availability from Coal-Fired Generation in the Near-Term, May 2001 -- http://www.nationalcoalcouncil.org; National Energy Technology Laboratory, "Lignite Fuel Enhancement Project," Power Engineering -- http://pepei.pennnet.com/

Thermal plumes emanating from Lake Macquarie power stations extend considerable distances from the hot water discharge points, extending over most of southern Lake Macquarie during summer. Far greater impacts than revealed in Delta's seagrass monitoring are, therefore, highly likely.

Thermal impacts on fish and marine communities

Thermal impacts on fish and other marine organisms vary depending on the species and severity of the temperature of the discharge water.[61] A 2007 Report by Delta Electricity[62] concluded temperatures as low as 25° C caused significant mortality of sea urchin larvae, and fish larvae were affected by temperatures of 28° C. The report found the LT50 or ET50s (elevated temperature that killed or severely impacted 50% of the test population) were between 27.5°C (mussel) and 32.2°C (polychaete), with fish and diatom about 28°C.[63]

Reductions in diversity and the number of species in response to the thermal plume have been observed for Wyee Bay at sites closest to the thermal discharge.[64] In general, for marine organisms, increased temperatures invoke increased growth and development to a threshold point above which rates decline.[65] A 1987 study showed complete extinction of some benthic species adjacent to the Vales Point outfall.[66] Declines in diversity and abundances reduced to 1-2 species of gastropods in shallow areas of Wyee Bay.[67]

Small increases in temperature can have a significant impact. For example, a 1975 study found the mortality of copepod, a numerous small crustacean, in the Vales Point cooling water outlet was 22% at 30.3°C; mortality almost doubled to 42% with an increase in temperature of just 2.1°C (32.4°C).[68]

A study in 2012,[69] found a significant relationship between temperature, nutrients and selenium and the diatom assemblages in Wyee Bay.[70] Diatoms are a significant, often dominant, component of the benthic microalgae of coastal systems[71] contributing up to 50% of primary production within estuaries.[72] Thus, changes in benthic diatom communities from thermal pollution could significantly affect ecological functioning in the Lake.

Ingleton & McMinn (2012) found the thermal plumes the power station discharge in Lake Macquarie affected benthic assemblages down to about 4.7 m.[73] Diatom assemblages are sensitive to as little as 1-2 degrees Celsius and the potential area affected by thermal pollution may be greater than

61 *Suresh K. Ahamed M.S. Duraiji G. & Nair K.V.K. (1993) Impact of power plant heated effluent on the abundance of sedentary organisms, off Kalpakkam, east coast of India. Hydrobiologia 268 109-114; Ambrose F.R. Schmitt R.J. & Osenberg C.W. (1996) Predicted and observed environmental impacts: Can we foretell ecological change? In: Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats (eds R.J); Keser M., Swenarton J. T. & Foeltch J.F. (2005) Effects of thermal input and climate change on growth of Ascophyllum nodosum (Fucales, Phaeophyceae) in eastem Long Island Sound (USA). J. Sea Res. 54, 211-220.*

62 *Delta Electricity, 2007. Assessment of Changes in Wyee Bay Seagrass Percent Cover in 2007 Relative to 1980 to 2007 Distribution Changes Delta Electricity 17 September 2007*

63 *Delta Electricity, 2007. Assessment of Changes in Wyee Bay Seagrass Percent Cover in 2007 Relative to 1980 to 2007 Distribution Changes Delta Electricity 17 September 2007*

64 *Hein, M.K., Koppen, J.D., 1979. Effects of thermally elevated discharges on the structure and composition of estuarine periphyton diatom assemblages. Estuarine and Coastal Marine Science 9, 385e401.*

65 *Mustard, J.F., Carney, M.A., Sen, A., 1999. The use of satellite imagery to quantify thermal effluent impacts. Estuarine, Coastal and Shelf Science 49, 509e524.*

66 *Robinson, K.I.M., 1987. Effects of thermal power station effluent on the seagrass benthic communities of Lake Macquarie, a New South Wales coastal lagoon. Wetlands (Australia) 7, 1e22.*

67 *Australian Water and Coastal Studies Pty. Ltd., 1995. Lake Macquarie estuary process study. Volume 1 Report. Prepared for Lake Macquarie Council in conjunction with JH Laxton and ES Laxton Pty Ltd, AWACS report 94/25, Nov. 1995, 170pp.*

68 *Waritswat, A, 1975. Master of Science Thesis School of Zoology, University of New South Wales. April, 1975. http://unsworks.unsw.edu.au/fapi/datastream/unsworks:54507/SOURCE01?view=true*

69 *Ingleton, Timothy & McMinn, Andrew. (2012). Thermal plume effects: A multi-disciplinary approach for assessing effects of thermal pollution on estuaries using benthic diatoms and satellite imagery. Estuarine, Coastal and Shelf Science. 99. 132-144. 10.1016/j.ecss.2011.12.024.*

70 *ibid*

71 *Sullivan, M.J., 1999. In: Stoermer, E.F., Smol, J.P.S. (Eds.), The Diatoms: Applications for the Environmental and Earth Sciences. Applied Diatom Studies in Estuaries and Shallow Coastal Environments. Cambridge University Press, Cambridge, pp. 334e351.*

72 *Kromkamp, J.C., de Brouwer, J.F.C., Blanchard, G.F., Forster, R.M., Creach, V., 2006. Functioning of Microphytobenthos in Estuaries. Royal Netherlands Academy of Arts and Sciences, Amsterdam, the Netherlands, ISBN 90-6984-453-2, pp. 262.*

73 *Ingleton & McMinn (2012) op cit*

that determined by seagrass impacts.[74] Small elevations in temperature for extended periods appear to invoke a biological response in diatoms.[75] Shifts in temperature regimes can drive changes in phytoplankton cell size and chemistry that in turn have secondary implications for food web dynamics.[76] Increased temperature was found to change diatom species compositions that alters the functioning of the sediment biofilm that affects estuarine nutrient cycling.[77] Ingleton and McMinn (2012) conclude that the depth to which thermal plume effects have been identified may have broader implications for the Lake's primary production.[78]

Impacts on seagrass

Seagrasses are flowering plants adapted to life in the shallow marine environment. They fulfil a number of ecological functions, including primary production, provision of habitat for many species of juvenile fish and crustaceans, and consolidation of sediments.[79] Two species of seagrass (see Figures 12 and 13), *Zostera muelleri ssp. capricorni* (Eelgrass) and *Halophila ovalis* (Paddleweed), are common in Lake Macquarie, including Wyee Bay and Chain Valley Bay. Impacts of thermal stress on seagrasses relate to mortality, morphological effects, impairment of photosynthetic processes, and disruption of molecular pathways. [80]

Laboratory experiments designed to examine the process of thermal stress on *Zostera muelleri ssp. capricorni*, found evidence of chronic damage to the photosynthetic apparatus of plants that had been acclimated to summer temperature conditions (25, 27, 30 °C) and then exposed to short-term (4 hr) pulses of heat (+5° C) over four consecutive days.[81]

It was clear that zostera seagrass exposed to temperatures above 30 °C for up to 4 hours over four consecutive days declined in health,[82] and Zostera acclimated to winter temperatures (18 °C) exposed to 28 °C temperatures showed significant declines in growth. [83] Past exposure to thermal stress has contributed to less dense, smaller patches of seagrass within Wyee Bay, which makes them more vulnerable to other disturbances.[84] During normal electricity supply conditions, hot water can be discharged up to a maximum of 35°C. However, a number of EPL variations led to Vales Point discharging to a maximum of 37.5°C for 250 hours, and up to 38.5°C to avoid electricity shortages.

The first seagrass monitoring by Delta Electricity since the Vales Point power station began discharging hot water into Wyee Bay in 1963, occurred in the early 1980s. It showed almost no seagrass (Zostera or Halophila) nearest to the hot water discharge at the southern end of Wyee Bay, which together with the north-eastern side of Wyee Bay is subject to the highest temperature increases. Indeed, very little Zostera was found anywhere in Wyee Bay having been replaced by the more thermally tolerant Halophila. After attemperation pumps were installed in 1985, Zostera, returned to the southern end of the bay. [85]

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74 *ibid*
75 *ibid*
76 *Finkel, Z.V., Beardall, J., Flynn, K.J., Quigg, A., Rees, T.A.V., Raven, J., 2010. Phytoplankton in a changing world: cell size and stoichiochemistry. Journal of Plankton Research 32, 119e137.*
77 *Underwood, G.J.C., 2005. Microalgal (microphytobenthic) biofilms in shallow coastal waters: how important are the species? Proceedings of the California Academy of Sciences 56, 162e169.*
78 *Ingleton & McMinn. (2012). Op cit*
79 *Larkum, A. W., McComb, A. J., & Shephard, S. A. (1989). Biology of seagrasses: a treatise on the biology of seagrasses with special reference to the Australian region (Vol. 1, No. 2, pp. 105-112). Elsevier Science Pub..*
80 *Ralph, P., Wilson, K., Hill, R., Petrou, K. (2008). Effects of Increased Temperature Pulses on Temperate Seagrass. Report for Eraring Energy by University of Technology, Sydney*
81 *Ralph et al (2008). Op cit*
82 *BIOANALYSIS 2022. Vales Point Power Station Seagrass Monitoring Project (2021/2022). Prepared for Delta Electricity Pty Ltd. Accessed under GIPA Act EPA 860.*
83 *Ralph et al. (2008). Op cit*
84 *BIOANALYSIS 2022. Op cit*
85 *Delta Electricity, 2007. Assessment of Changes in Wyee Bay Seagrass Percent Cover in 2007 Relative to 1980 to 2007 Distribution Changes Delta Electricity 17 September 2007*

Figure 12. Halophila ovalis (Paddleweed)

Figure 13. Zostera muelleri ssp. capricorni (Eelgrass)

The first of many EPL variations that allowed Delta to increased thermal pollution was issued in 2005, for an increase in discharge temperature of 2.5ºC (from 35ºC to 37.5ºC) for a maximum of 69 hours a year to avoid potential shortfall of electricity supply.[86] Such an increase in temperature was likely to impact the remaining seagrass in Wyee Bay and Delta was required to conducted a study into the effects on seagrass and other marine life and report the results to the EPA by 2007.

The 2007 Delta seagrass report, and a similar report by Eraring Energy, then owner of Eraring power station, exhibited poor ecological understanding and were described in an internal NSW Fisheries report as so biased in their interpretation to be almost worthless. However, Government Department officers were well aware of the obvious pattern of seagrass loss in the area affected by the hot-water plumes with substantial and sustained initial losses of seagrasses documented following commissioning Eraring and Vales Point power stations.

In 2007 Delta's seagrass mapping [87] showed Zostera only inhabited 2 percent of the 1-2m zone in Wyee Bay and in the deeper water Zostera was replaced entirely by Halophiia. In the shallow waters, macroalgae percent cover in Wyee Bay was over 3-times higher than the Crangan Bay locations. Zostera cover in the 1-2m zones of Crangan Bay and Chain Valley Bay were almost 100 percent cover. Macroalgae was absent from the Crangan Bay locations.

While the percent cover of Halophila in Wyee Bay was found to be nearly 100-times higher than the average of the locations in Crangan Bay, it was only 4-times higher than Chain Valley Bay. Vales Point power station operates six attemporation pumps to minimize cooling water temperatures. However, in mid-summer, at ambient maximum temperatures, the cooling water outflow begins to affect the temperature of the cooling water inflow.[88]

Most coastal fisheries are dependent on seagrass as nursery habitat and some invertebrates feed directly on epiphytes growing on the leaf blades. Large-leafed species such as zostera provide far greater habitat than the finer species, such as Halophila ovalsis.[89]

The 2007 Report by Delta Electricity[90] concluded:

- Zostera capricorni declined in health when exposed to short-term pulses of heat. The upper thermal limit of Zostera is close to 30°C.
- There was no evidence of enhanced growth due to slightly ele1vated temperatures.
- Zostera acclimated to winter temperatures showed significant declines in growth when exposed to 28°C.

In 2009, Delta once again sought to be allowed to increase the number of hours of hot water discharge between 35 ºC and 37.5ºC (to 200 hours) to counter shortfall in electricity. A 2009 internal Report by the UTS[91] prepared for the EPA found thermal stress on the seagrasses *Zostera capricorni* exposed to 4 hour pulses of +5ºC and +10ºC above ambient temperatures over three consecutive days and monitored for recovery over the ensuing 10 days. The study found *Z. capricorni* declined in health on a number of parameters when exposed to short-term pulses of heat. Ambient temperature of 30 ºC resulted in declines in all parameters for both controls and treated samples, which confirmed the upper thermal limit for *Z. capricorni* as being close to 30 ºC. Thermal stress during winter (18ºC ambient +10ºC) showed a significant decline in growth; indicating that seagrass distribution and condition would be reduced during winter if thermal pulses of this magnitude where applied to a seagrass meadow. Despite the study, and Delta's 2009 seagrass monitoring report finding a total loss of above-ground biomass (leaves) of Zostera over the entire Wyee Bay, the EPA agreed to vary this aspect of licence until 2010.. However, the Special discharge temperature conditions was ultimately extended to 2016.

In November 2016, Vales Point EPL was varied once again to allow up to 262 hours annually when cooling waters could be discharged up to 37.5ºC. Delta proposed to use the additional hours to maintain the generation load for longer on days when the discharge temperature exceeds 35ºC and when load demand is high. This period of high demand typically occurs in the late afternoon and early evening peak

86 *EPL, 2005. Variation 1053558 for EPL 761.. See https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?instid=761&id=1053558&option=notice&range=POEO%20licence&noticetype=*
87 *Delta Electricity, 2007. Op cit*
88 *Pers Comm Justin Flood.*
89 *Institute for Water and Environmental Resource Management - University of Technology, 2009. Effects of Increased Temperature Pulses on Temperate Seagrass. Report for Department of Environment and Climate Change (DECC). Accessed under GIPA Act EPA 860*
90 *Delta Electricity, 2007. Op cit*
91 *Institute for Water and Environmental Resource Management - University of Technology, 2009. Effects of Increased Temperature Pulses on Temperate Seagrass. Report for Department of Environment and Climate Change (DECC). Accessed under GIPA Act EPA 860*

period on particularly hot days between December and February. The EPA retained the right to vary the temperature limits after August 2021 following further reviews of studies.

In response to significant electricity demand during heat wave conditions in February 2017, the EPA, once again varied the Vales Point Power Station licence to allow the EPA or AEMO to consider the function of the NSW electricity supply and allow the operator to maintain or increase power generation, for system security, and may exceed the maximum operating hours above 35°C and the maximum temperature specified in conditions for 72 hours from the date and time of the direction or approval. [92]

The maximum temperature of the Vales Point thermal discharge increased from 36.6^{0}C in 2015/16 (112 hours above 35^{0}C) to 38.1^{0}C in 2016/17 (7 hours above 37.5^{0}C).[93] In the same year, average water temperatures in Wyee Bay exceeded 30^{0}C for between 1,200 and 1,519 hours.[94] Delta's seagrass monitoring report submitted to the EPA in 2016/17 identified that except for small, isolated remnant patches most distant from the thermal discharge point, Zostera cover in Wyee Bay was absent.[95]

In 2018, Delta further applied for an increase in the number of hours the hot water could be discharged between 35°C and 37.5°C from 262 to 350 hours per year, with an additional 18 hours between 37.5°C and 38°C per year. However, an OEH report for the EPA concluded that the increase in hours granted in November 2016 appeared to have resulted in the systematic loss of Zostera in Wyee Bay, while seagrass populations elsewhere in Lake Macquarie had remained largely unchanged over the same period.[96] Following further consultation, Delta withdrew its application to vary the Licence.

Temperatures measured at the hot water outlet exceeded 35 °C for 109 hours between 1 January and 31 March 2020, compared to 299 hours in 2018/2019; In the north of the bay, water temperatures exceeded 35°C for far fewer hours in 2019/2020 (i.e. 3 hours) than in 2018/2019 (i.e. 13 hours). While the significant increase in thermal pollution in Wyee Bay coincided with a near total loss of Zostera, it is not clear whether the critical factor for the loss of Zostera is the acute effects of high temperature in summer, loss of resilience due to higher-than-normal temperatures in winter, or a combination of the two. [97]

Cover at some sites decreased from 80% in 2016 to less than 10% in 2018 and zero in 2019, completing the trend of loss of Zostera in Wyee Bay that was first evident in 2015.[98] There was also, for the first time since the current monitoring began, complete loss of the heat tolerant Halophila seagrass nearest to the hot water outlet.

Delta's 2021 monitoring report detailed a 57% increase in the area of seagrass mapped within Wyee Bay, in comparison with the 2019/2020 monitoring period. This was after a 90% reduction in the number of hours of hot water discharge above 35°C from 109 hrs 2019/20 to 12 hours in 2020/21 (12 hours).

In 2021, after a great deal of obfuscation and blame shifting over the almost complete loss of seagrass from Wyee Bay, the EPA finally remove the special exemption that allowed Delta to discharge its hot water above 35.oC approved in 2016. The 2021 EPL Variation establishes that Zostera seagrass losses correlated with increased hours of hot water discharge exceeded 35°C and concluded that "Under the Power Station's current operations, the broader re-establishment of Zostera in Wyee Bay is unlikely".[99] Delta's 2021/22 seagrass monitoring[100] showed Zostera cover decreased significantly in the north of Wyee Bay, from 72% to 18% and from 82% to 63% compared to 2020/21.

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92 *EPA, 2017. Variation 1549284 for EPL 761.*

93 *Cardno, 2019. Vales Point Power Station Ecological Monitoring of Seagrasses – 2019.*

94 *Scanes, P., and Krogh, M., 2018. Sustainable Temperature for Zostera in Wyee Bay, Lake Macquarie. Report by Water Wetlands and Coastal Science NSW Office of Environment and Heritage for NSW EPA.*

95 *ibid*

96 *Smith, T., Raoult, V., Glasby, T. and Gaston, T., 2019. Do increasing temperatures affect the reproductive effort of seagrass in Lake Macquarie? Lake Macquarie Seagrass Reproduction. Report for NSW Government by the University of Newcastle. Accessed under GIPA Act.*

97 *Scanes, P., and Krogh, M., 2018. Sustainable Temperature for Zostera in Wyee Bay, Lake Macquarie. Report by Water Wetlands and Coastal Science NSW Office of Environment and Heritage for NSW EPA. (Accessed under GIPA Act)*

98 *EPA, 2021. EPL 761, s.58 Licence Variation 1613778. https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?instid=761&id=1613778&option=notice&range=POEO%20licence&noticetype=*

99 *EPA, 2021. EPL 761, s.58 Licence Variation 1613778. https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?instid=761&id=1613778&option=notice&range=POEO%20licence&noticetype=*

100 *BIOANALYSIS 2022. Vales Point Power Station Seagrass Monitoring Project (2021/2022). Prepared for Delta Electricity Pty Ltd. Accessed under GIPA Act EPA 860.*

The 2021/22 monitoring measured:

- 18 % increase in the number of hours over 32°C at the Outlet between 2020/21 (397 hours) and 2021/22 (484 hrs).
- Seagrass meadows in the northeast of Wyee Bay exceeded 30°C for longer during 2021/22 (436 hours; max 33.7°C) than during 2020/21 (for 322 hrs; max 33.8°C), representing a 26% increase in exposure of seagrasses at that location to thermal stress.
- There was a similar increase in the number of hours over 30°C in seagrass in the northwest of Wyee Bay from 328 hours in 2020/21 to 436 hours in 2021/22.

To reduce the temperature at the outlet, Vales Point operates six attemporation pumps that draw additional water from the intake at Chain Valley Bay and added to the hot water discharge. We have been told by Delta staff that the thermal plume can extend around the point and substantially increase the temperature of the intake water.[101] Table 1 below sets out that the cooling water intake temperatures over 30°C occurs in most years. This nullifies the utility of running the attemporation pumps at the very times that they are needed most, when the power station is operating at peak loads on hot summer afternoons. The maximum temperature of the Vales Point cooling water inlet was measured in 2016/17 at 31.9 °C, about 8°C above average ambient Lake temperature.[102]

This may also be having an impact on seagrass beds in Chain Valley Bay. A recent seagrass survey for Delta Coal found *Halophila ovalis* seagrassfor the first time in 2010. Prior to this survey, the only seagrass observed within Chain Valley Bay was Zostera. [103]

Table 1: Vales Point cooling water inlet temperatures 2013/14 to 2021/22

Location	Year	Range min-max	Hours (%) =or> 30C	Hours (%) =or> 32C	Hours (%) =or> 34C	Hours (%) =or> 35C
Inlet	2021/22	21.6-29.9	0	0	0	0
	2020/21	23.1-29.1	0	0	0	0
	2019/20	22.5-31	52 (2.4%)	0	0	0
	2018/19	22.1-31.4	96 (4%)	0	0	0
	2016/17	24.2-31.9	56 (4%)	0	0	0
	2015/16	25.2-30	2 (<1%)	0	0	0
	2014/15	25.2-31.5	266 (12%)	0	0	0
	2013/14	23.4-30.8	7(<1%)	0	0	0

101 *Pers Comm Justin Flood.*
102 *Cardno, 2019. Vales Point Power Station Ecological Monitoring of Seagrasses – 2019.*
103 *J.H. & E.S. Laxton - Environmental Consultants, 2020. Delta Coal Mannering & CVC Collieries Seagrass Survey of Chain Valley Bay, Summerland Point, Bardens Bay and Crangan Bay, Lake Macquarie, NSW. https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-5465-PA-16%2120200601T000750.429%20GMT*

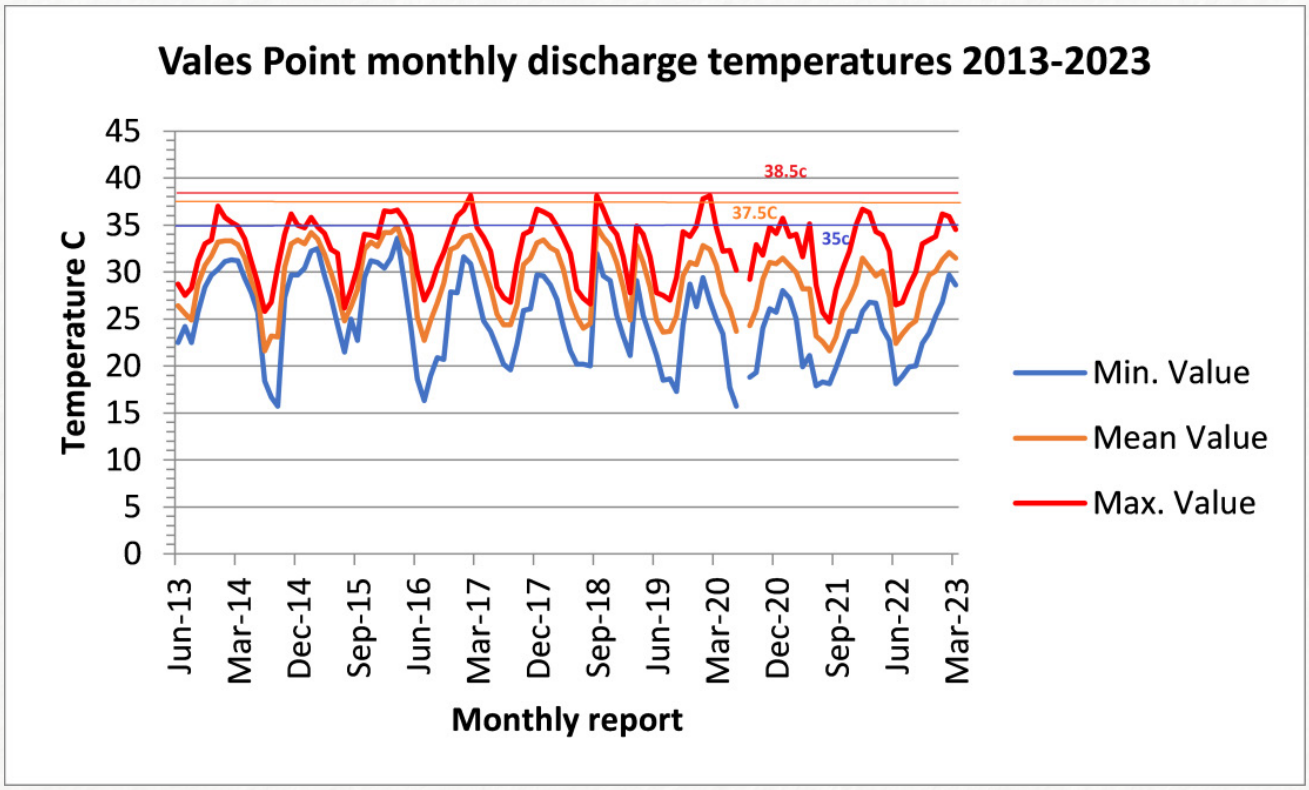

Figure 14: Vales Point hot water discharge temperatures 2013-2023 . [104]

Figure 14 above (see also Table 2 and Appendix 1) shows Vales Point hot water discharge temperatures (min., mean, and max.) from 2013 to 2023. It shows, in most years, a far greater temperature differential in winter compared to summer. Maximum temperatures of the discharge did not exceed 37.5°C until the 2016/17 summer, and since the 2019/20 summer has not exceeded 37.7°C. June 2020 temperatures were not recorded by Delta in its monthly monitoring results (See appendix 1).

Monthly maximum and minimum thermal discharge temperatures have been reported in EPL monthly monitoring reports since 2013 (See Appendix 1). Since 2013, discharge temperatures above 35°C and below 37.5°C have occurred 23 times (See Table 2), and just four times over 37.5°C (See Table 3)

Table 2: Vales Point monthly thermal discharge between 35oC-37.5oC - June 2013 to June 2020

Dec-13	**30.3**	**33.2**	**37**
Jan-14	**31.1**	**33.3**	**35.8**
Feb-14	**31.3**	**33.3**	**35.3**
Nov-14	**29.7**	**33**	**36.2**
Dec-14	**29.7**	**33.4**	**35**
Feb-15	**32.2**	**34.2**	**35.8**
Jan-16	**30.4**	**34.2**	**36.5**
Feb-16	**31.5**	**34.2**	**36.4**
Mar-16	**33.6**	**34.8**	**36.6**
Apr-16	**29**	**32.7**	**35.6**
Dec-16	**27.8**	**32.7**	**35.95**
Jan-17	**31.6**	**33.7**	**36.6**

104 *Delta Electricity, EPL monthly monitoring -https://www.de.com.au/environment/environmental-licences-and monitoring?retain=true&PagingModule=877&Pg=1*

Dec-17	29.7	33.1	36.7
Jan-18	29.6	33.4	36.4
Feb-18	28.6	32.6	36
Oct-18	29.6	33.7	36.7
Jan-21	28	31.5	35.7
May-21	21.1	28.2	35.1
Dec-21	23.7	28.7	35
Jan-22	25.8	31.5	36.7
Feb-22	26.8	30.5	36.3
Jan-23	26.8	31.3	36.2
Feb-23	29.7	32.1	35.9

Table 3: Vales Point monthly thermal discharge between 35.5°C-37.5°C - June 2013 to June 2020

Month report-ed	Mean C	Min. C	Max C.
Feb-17	30.9	33.9	38.1
Sep-18	32	34.8	38.1
Jan-20	29.4	32.8	37.8
Feb-20	26.9	32.4	38.1

Figure 15 and 16 shows Delta's seagrass monitoring sites, with Figure 15 also displaying the 2008 DPI Fisheries seagrass mapping showing Zostera fringing southern Lake Macquarie with the exception of southern Wyee Bay and Chain Valley Bay. After 2008 a significant decline in the areas of seagrass in Wyee Bay became apparent.

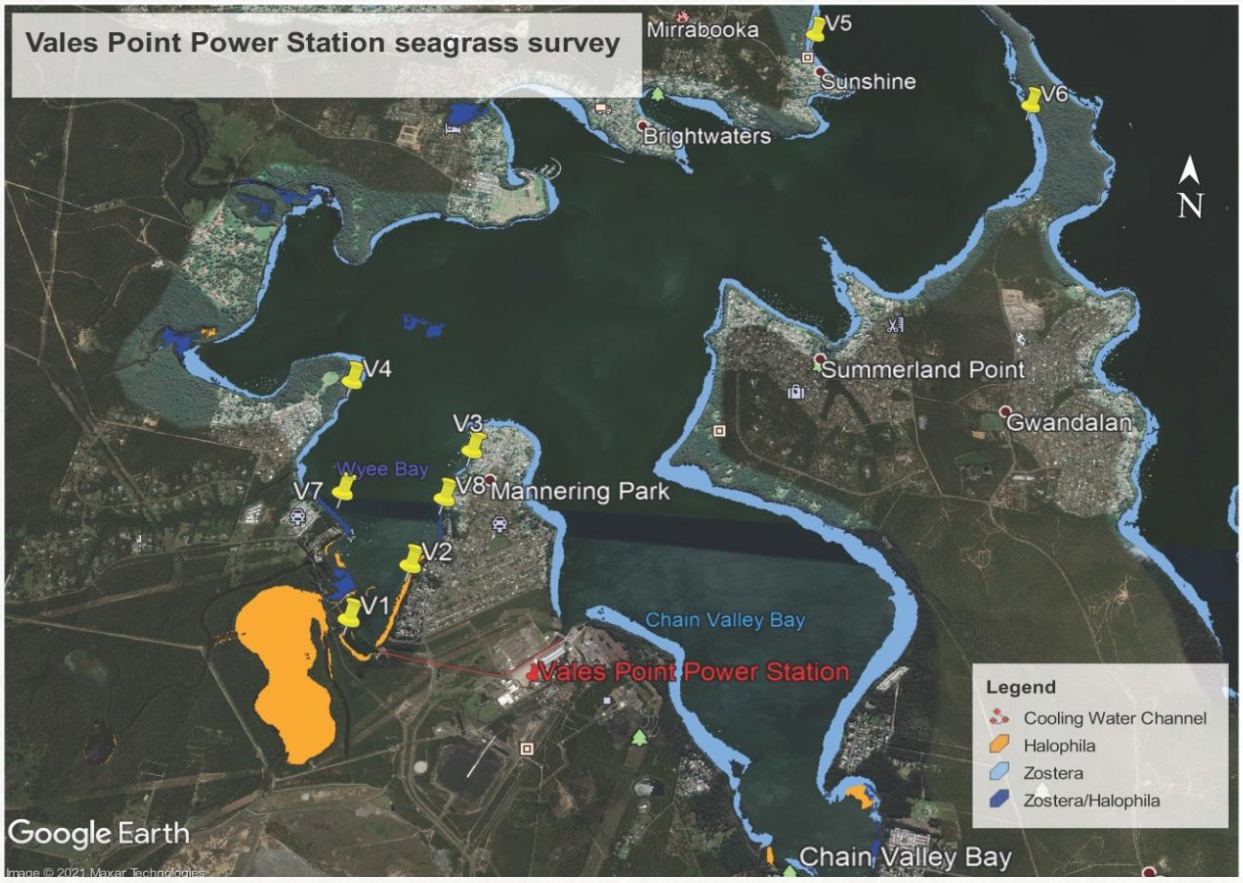

Figure 15. Seagrass monitoring points and DPI Fisheries mapping 2008 (from 2006/2007 air photos.

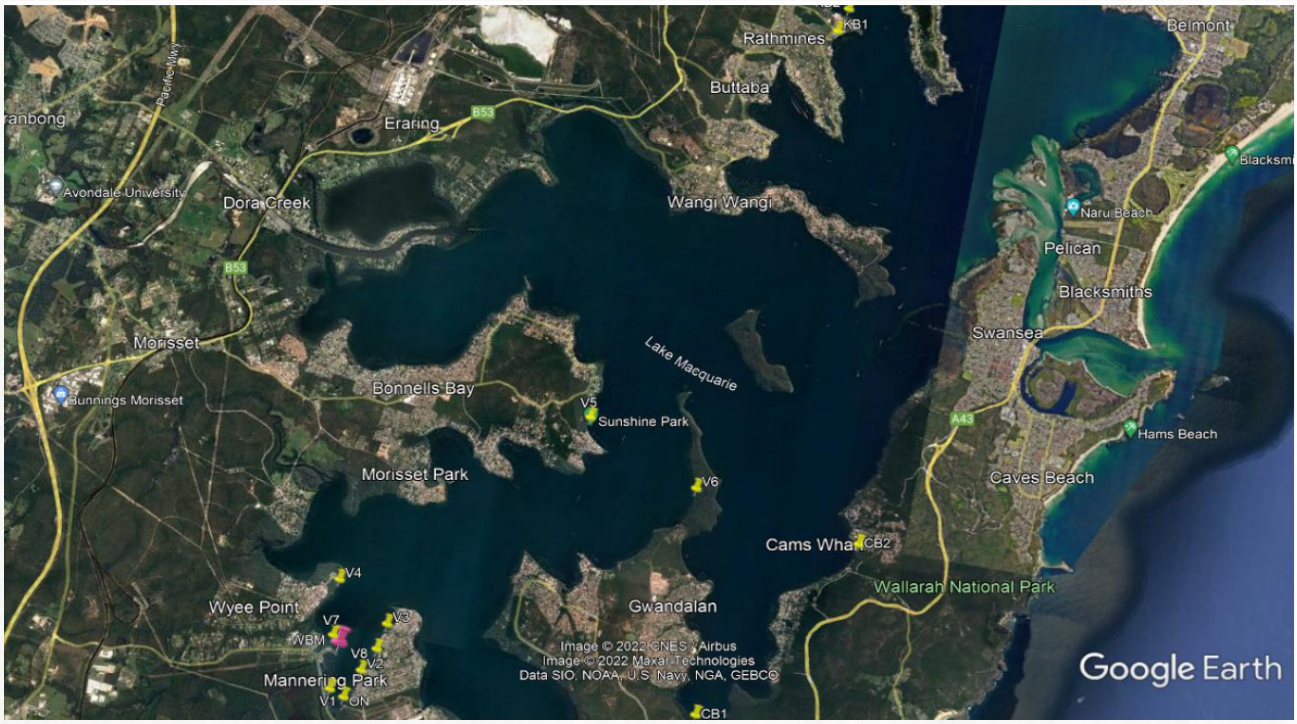

Figure 16. Vales Point seagrass monitoring points

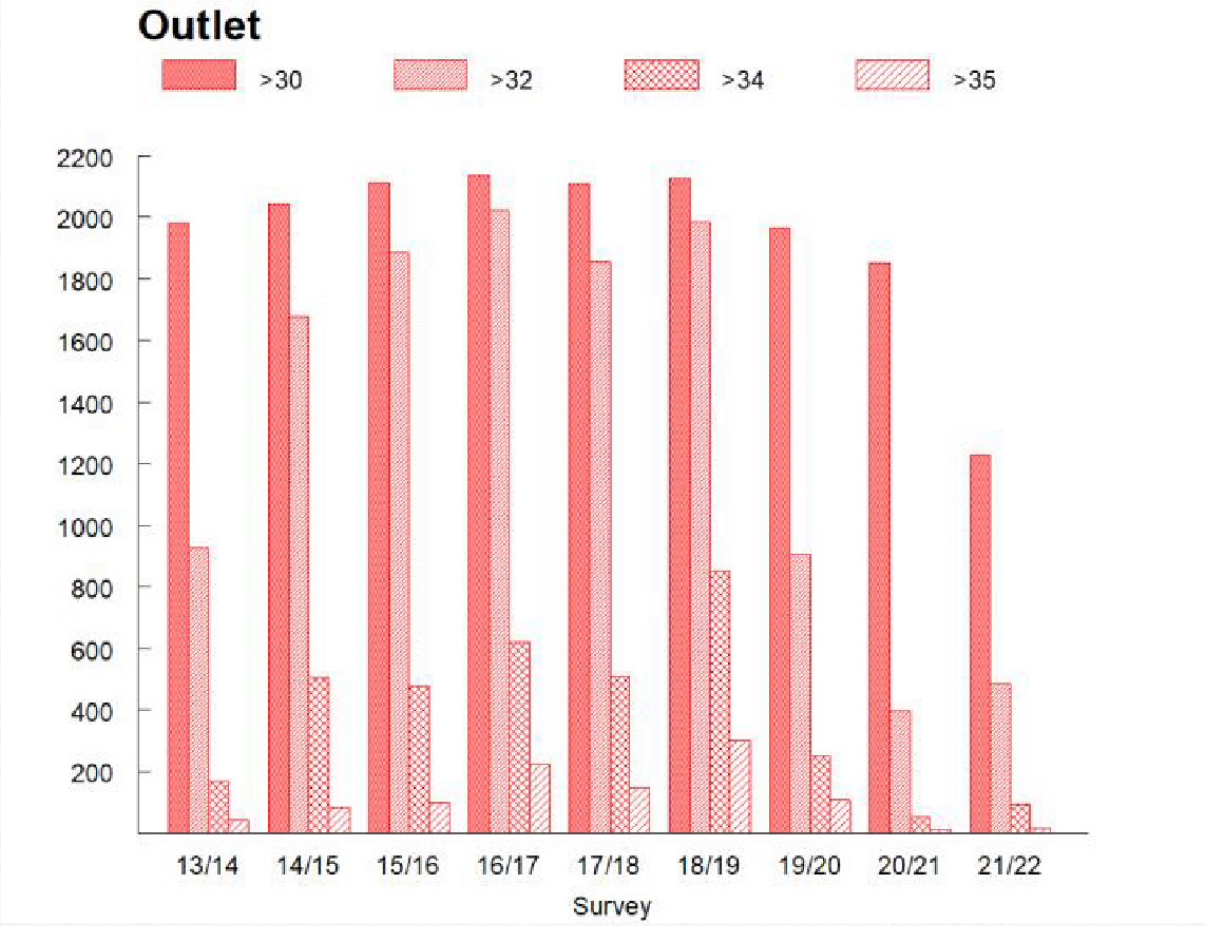

Figure 17. Vales Point hot water discharge temperatures 2013-2022

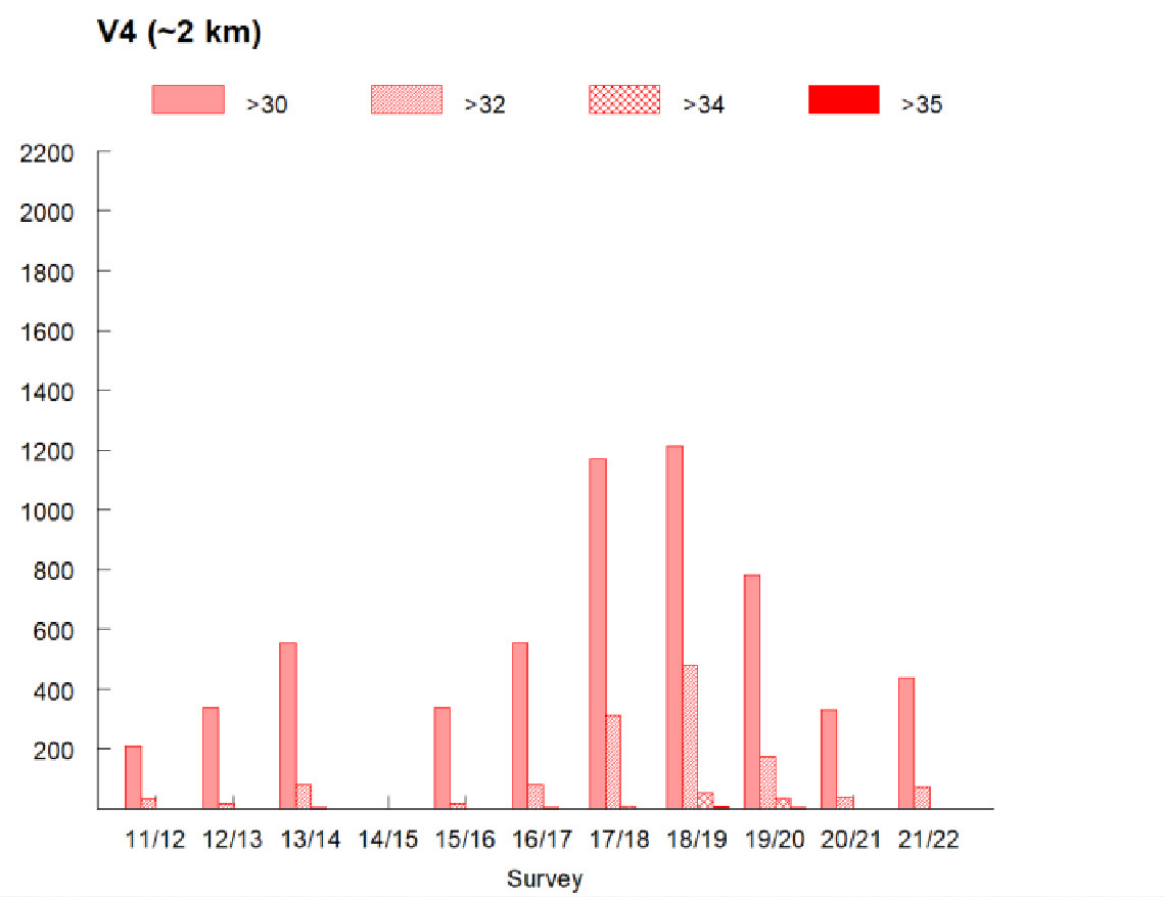

Figure 18. Water temperature in Wyee Bay (V4) 2km from hot water discharge point 2011-

Figure 17 shows discharge temperatures between 2013/14 and 2021/22 remained above 30^{0}C for around 2000 hours for all years but 2021/22. The number of hours that the discharge temperatures were over 35^{0}C were highest in 2018/19 (~300 hours), which is also the year of the greatest number of hours (1233) when water temperatures were over 30^{0}C 2km from the discharge (V4), at the northern end of Wyee Bay. In September 2018 discharge temperatures reached 38.1^{0}C which corresponded to the 2018/19 seagrass monitoring revealing the near total loss of Zostera from Wyee Bay (See Table 4).

Table 4 : Hours above 30oC,32oC, 34oC, and 35oC at monitoring locations -BIOANALYSIS 2022.

Location	Year	Range min-max	Hours (%) =or> 30C	Hours (%) =or> 32C	Hours (%) =or> 34C	Hours (%) =or> 35C
Outlet	2021/22	23.8-36.6	56.90%	22.40%	4.30%	0.60%
	2020/21	25.8-35.6	85.80%	18.40%	2.40%	0.60%
	2019/20	26.6-37.7	91.10%	41.90%	11.60%	5%
	2018/19	27.5-38.1	98.50%	92%	39.50%	13.90%
	2017/18	28.6-36.7	97.70%	85.90%	23.50%	6.80%
	2016/17	27.7-38.1	98.90%	93.70%	28.80%	10.40%
	2015/16	28.1-36.6	96.70%	86.40%	21.80%	4.50%
	2014/15	27.8-36.5	94.50%	77.10%	23.40%	3.90%
V4	2021/22	22.4-33.7	20.20%	3.30%	0.00%	0.00%
	2020/21	24.2-33.2	15.20%	1.80%	0.00%	0.00%
	2019/20	23.4-35.5	35.60%	7.90%	160.00%	0.10%
	2018/19	23.4-35.4	56%	22%	2.00%	0.00%
	2017/18	24.8-34.4	54.20%	14.50%	20.00%	0.00%
	2013/14	24.5-34.6	28%	4%	<1%	0.00%
	2012/13	23.1-33	16%	1%	0.00%	0.00%
	2011/12	21.7-33.2	10%	1%	0.00%	0.00%

A 2014 study[105] found that *Zostera muelleri* in Lake Macquarie uses clonal growth as a means of rapidly recovering from small-scale disturbances, and that sexual recovery from seeds play little to no part in recovery at small spatial scales. Recovery via asexual rhizome (root system) encroachment from high-intensity disturbance ranged from 18-35 weeks, whereas the ability to recover was lost when recovery depended on sexual regeneration, suggesting that seeds do not provide a mechanism of seagrass recovery in Lake Macquarie against intense small-scale disturbances. This is a significant observation, as seagrass recovery within Wyee Bay will be determined by the persistence of rhizomes. As Delta's seagrass monitoring has not, to date, monitored seagrass rhizome extent, it cannot determine the temperatures at which recovery of Wyee Bay seagrass will occur.

105 *Macreadie, P. I., York, P. H., & Sherman, C. D. (2014). Resilience of Zostera muelleri seagrass to small‐scale disturbances: the relative importance of asexual versus sexual recovery. Ecology and evolution, 4(4), 450-461.*

Where did all the seagrass go?

A study of the ecology of Lake Macquarie in 1959,[106] cited a survey in August 1953 that showed that at that time seagrass covered 2,072ha -- Zostera covered 1399ha, Ruppia 466ha and Posidonia 207ha of Lake Macquarie. The 1959 study stated that: Lake Macquarie is almost surrounded by a fringe of Zostera of greater or less width, interrupted where the cliffs drop steeply into deep water...In general, growth was more dense in the southern part of the lake than in the north.

Interestingly, Wood (1959) did not identify any Halophilla[107], of which the 2012 DPI Fisheries mapping identified 2.9ha, as well as 51.2 ha of Zostera/ Halophilla.

Department of Primary Industries, Fisheries published seagrass maps of Lake Macquarie show mixed Zostera/halophila in Wyee Bay in 2001 and 2008. However, in the 2012 mapping, both Zostera and Halophila are absent from all but the northern west end of the bay. While pure Zostera beds would have naturally fringed Wyee Bay before Vales Point A began operating in 1963, Halophila appears to have dominated the Bay since. However, a large reduction in Halophila between 2008 and 2012 coincides with the variation to Vales Point's EPL to discharge up to 200hrs between 35^{0}C and 37.^{0}C to counter shortfall in electricity.

DPI Fisheries seagrass mapping identifies that between 2008 and 2012 southern Lake Macquarie lost 34 percent of its seagrass, compared to a 4 percent increase in seagrass cover in northern Lake Macquarie.

Table 3: Comparative seagrass loss in north and south Lake Macquarie between 2001 and 2012 based on DPI Fisheries seagrass mapping.

Seagrass	All of Lake Macquarie					North Lake Macquarie					South Lake Macquarie				
	2001 (ha)	2008 (ha)	2012 (ha)	Change (ha)	Change (%)	2001 (ha)	2008 (ha)	2012 (ha)	Change (ha)	Change (%)	2001 (ha)	2008 (ha)	2012 (ha)	Change (ha)	Change (%)
Zostera	1153	1153	1042	-111	-10	431	431	495	63	15	722	723	548	-175	-24
Ruppia	85	85		-85	-100	8	8		-8	-100	77	78		-78	-100
Zostera/Ruppia	58	58		-58	-100						58	58		-58	-100
Halophila	16	16	3	-13	-81						16	16	3	-13	-81
Zostera/Halophila	63	63	51	-12	-19	35	35	29	-6	-17	28	28	22	-6	-22
Posidonia	88	88	98	10	12	87	87	98	11	12	1	1		-1	-100
Posidonia/Zostera	1	1	0.5	-1	-51	0.9	0.9	0.5	-0.4	-43					
TOTAL	1677	1678	1387	-291	-17	723	723	753	30	4	955	955	635	-321	-34

Between 2008 and 2012, southern Lake Macquarie lost 175 hectares or 24 percent of its Zostera cover, with the northern Lake seeing an increase in Zostera cover of 63 ha (15%). Over the same period, Lake Macquarie lost all its Ruppia (85ha), however, the loss was greatest in the southern Lake with 58 hectares lost. Halophila only ever existed in the southern Lake, 81 percent of which was lost by 2012, as well as 21 percent of mixed Zostera/Halophila beds. The northern Lake also saw a small increase in Posidonia cover (11ha); a promising sign for this Endangered species.

106 *Wood EJF (1959) Some Aspects of the Ecology of Lake Macquarie, N.S.W., with Regard to an Alleged Depletion of Fish. VI. Plant Communities and their Significance. Marine and Freshwater Research 10, 322-340. https://doi.org/10.1071/MF9590322*

107 *Cf Thomson, J.M., 1953. Summary Review of a Scientific Survey of Lake Macquarie. CSIRO Division of Fisheries and Oceanography REPORT 26. Marine Biological Laboratory Cronulla, Sydney., reported sparsely distributed Halophila was found at depths between 10 and 30 feet.*

Table 4: Seagrass loss in Lake Macquarie and Wyee Bay and Myuna Bay between 2008 and 2012.

Seagrass	Eraring Rocky Point to Goonda Point inc. Whiteheads Lagoon					Vales Point Wyee Point to Vales Point inc. Mannering Bay					Total power station influence				
	2001 (ha)	2008 (ha)	2012 (ha)	Change (ha)	Change (%)	2001 (ha)	2008 (ha)	2012 (ha)	Change (ha)	Change (%)	2001 (ha)	2008 (ha)	2012 (ha)	Change (ha)	Change (%)
Zostera	30	30	22	-8	-27.4	37.5	37.5	21.7	-16	-42	68	68	44	-24	-36
Halophila			1.1	1.1	100	11.5	11.6	0.2	-11	-98	11.5	11.6	1.3	-10	-89
Zostera/Halophila	3.6	3.6	4.4	0.8	23.2	5.7	5.7	0	-6	-100	9.28	9.28	4.41	-5	-52
Posidonia															
Posidonia/Zostera															
Ruppia															
Zostera/Ruppia															
TOTAL	35	35	30	-5.42	-15.5	54.8	54.8	21.8	-33	-60	89.9	89.9	51.5	-38	-43

In the thermal plumes of Eraring and Vales Point, the area of seagrass lost between 2008 and 2012 amounts to 38 hectares, a 43 percent loss of seagrass cover within the cooling water thermal plumes. Most of this loss (33ha) is in Wyee Bay.

The area of pure Zostera beds lost near both power stations amounts to 24 hectares. While a small increase in areas of Halophila and mixed Zostera/ Halophila seen near Eraring, Wyee Bay lost all its Halophila and mixed Zostera/Haliphila.

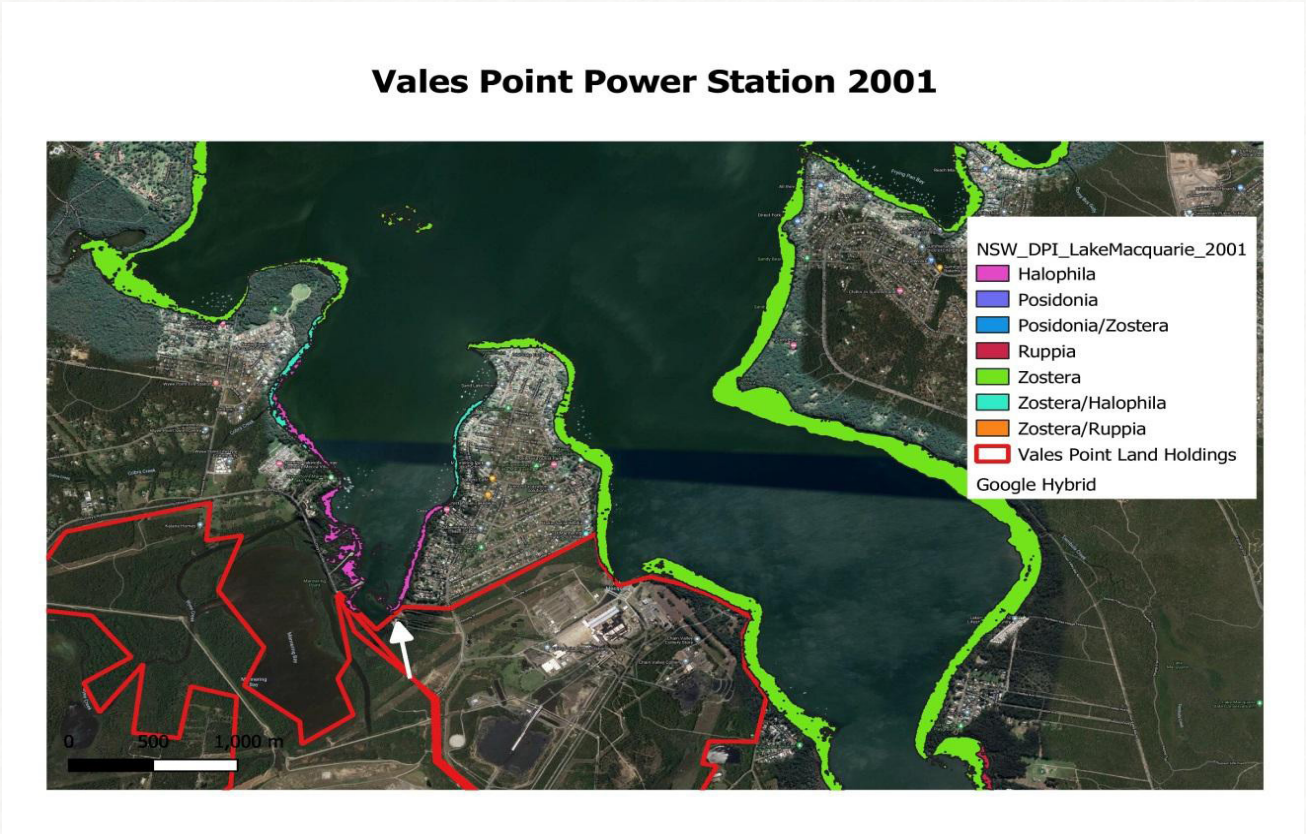

Figure 19. DPI Fisheries 2001 seagrass mapping of Wyee and Chain Valley Bays extrapolated from 1999/2000 aerial photographs

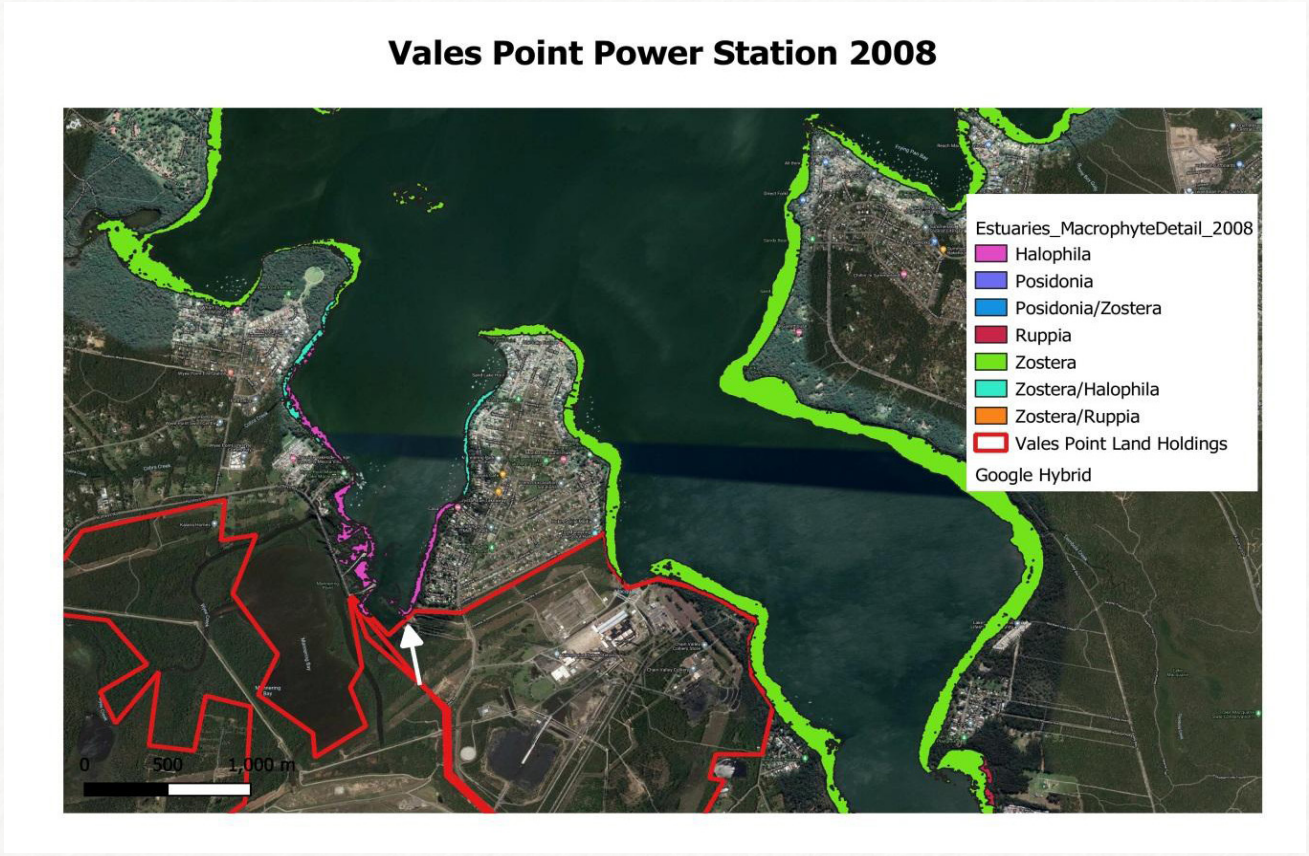

Figure 20. DPI Fisheries 2008 seagrass mapping of Wyee and Chain Valley Bays extrapolated from 2006/2007 aerial photographs

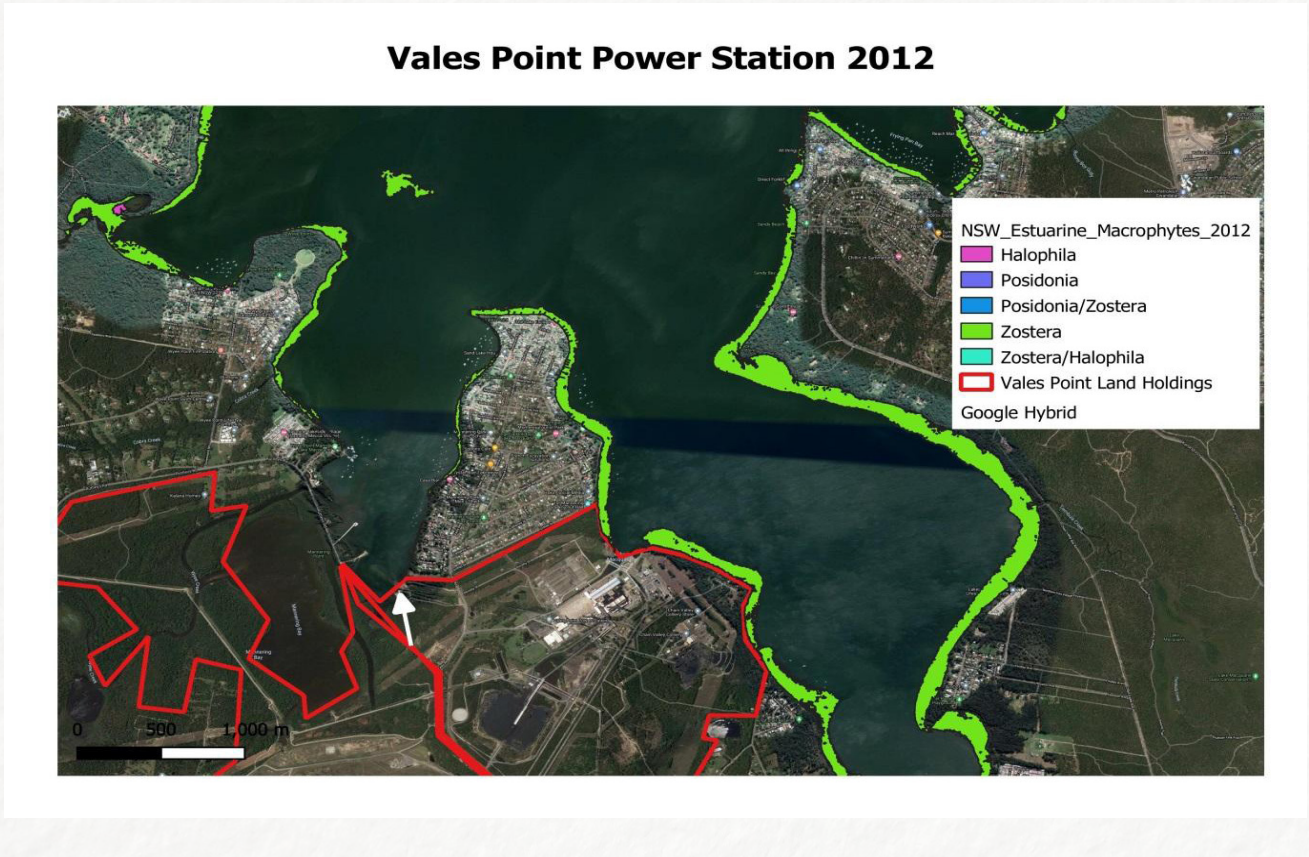

Figure 21. DPI Fisheries 2012 seagrass mapping of Wyee and Chain Valley Bays extrapolated from 2010/2011 aerial photographs

Figure 22. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 15/10/13

Figure 23. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 3/6/14

Figure 24. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 26/9/17

Figure 25. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 8/2/18

Figure 26. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 24/3/19

Figure 27. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 5/9/20

Figure 28. HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps image 12/6/21

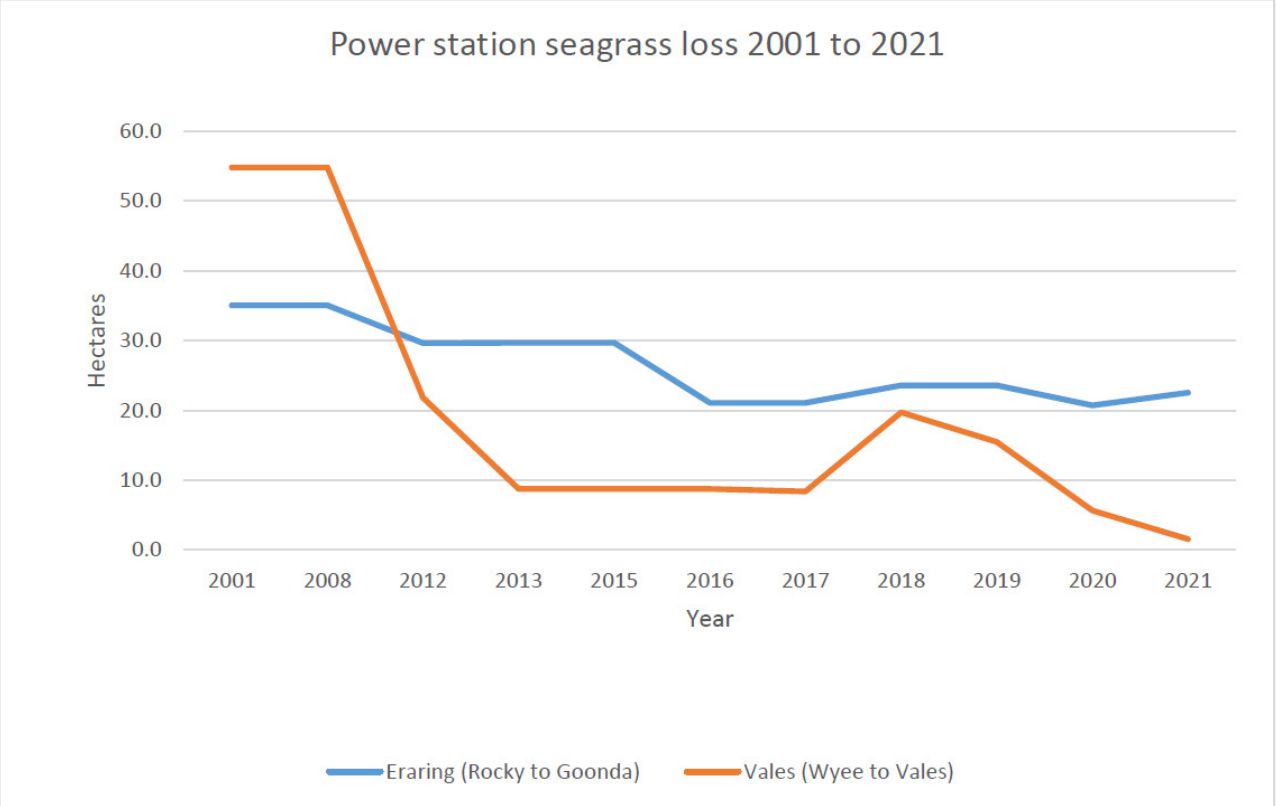

Figure 29. Lake Macquarie power station seagrass loss from DPI Fisheries and HCEC seagrass mapping of Wyee and Chain Valley Bays extrapolated from Nearmaps images.

DPI Fisheries and HCEC seagrass mapping of Wyee extrapolated from Nearmaps images indicates about 55ha of seagrass loss in Wyee Bay over the period 2008 to 2021.

A 2018 report by the then Office of Environment and Heritage[108] questioned whether a reduction in the temperature of hot` water discharged from Vales Point would lead to Zostera being re-established, as the level of stress from the still significant elevated temperatures that occurred prior to 2016-17. The Report recommended, "as an interim measure to protect the scant remaining Zostera in Wyee Bay and to re-establish the potential for recolonization, a temperature discharge regime similar to that existing prior to 2016-17 needs to be re-established".[109] However, the first temperature increase of Delta EPL discharge limit from 35^{0}C to 37.5^{0}C occurred in 2005 for 69 hours a year. Our assessment based on DPI Fisheries seagrass mapping suggests that a major reduction (47%) in Zostera seagrass in Wyee Bay occurred between 2006/7 and 2010/11. We, therefore, believe to encourage the regrowth of Zostera in Wyee Bay, the maximum hot water discharge temperature must be brought down to the original approved temperature of 35^{0}C.

Seagrass in south eastern Australia have been calculated to enhance commercial fishery production by $230 000 ha a year.[110] According to this calculation, the loss of almost 55ha of seagrass from Wyee Bay since 2005 equates to about $12.6M a year of lost commercial fishery production, and over the period 2005 to 2023 commercial fisheries of south eastern Australia has suffered a combined loss of about $226.8M.

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108 *Scanes, P., and Krogh, M., 2018. Sustainable Temperature for Zostera in Wyee Bay, Lake Macquarie. Report by Water Wetlands and Coastal Science NSW Office of Environment and Heritage for NSW EPA. (Accessed under GIPA Act)*

109 *The first temperature increase of Delta EPL discharge limit from 35oC to 37.5oC was in 2005 for 69 hours a year.*

110 *Blandon A, Zu Ermgassen PS. Quantitative estimate of commercial fish enhancement by seagrass habitat in southern Australia. Estuarine, Coastal and Shelf Science. 2014;141: 1-8.*

Vales Point Ash Dam

The 18 meter deep Vales Point Ash Dam was constructed in the natural valley of Mannering Creek, from a ridge to the south towards the north east and Lake Macquarie. Up until 1995, the dam discharged directly into Mannering Bay which adjoins Wyee Bay.

Originally built in 1962 to accept coal ash from Vales Point and Munmorah Power Stations, the ash dam was expanded in 1982 to increase its capacity to 30 million m^3, sufficient to accept ash from both Munmorah and Vales Point power stations to about 2000. The 1982 augmentation also included the construction of the Wyee channel to divert the flow of Mannering Creek to the newly constructed Wyee Dam wall. The ash dam now discharges into Wyee Creek. The Dam was built to ameliorate flooding of Wyee caused by the raising of the ash dam 8m to 25m using natural clay fill and coal washery refuse.

Figure 30: Original ash dam overflow into Mannering Bay

In 1995 the ash dam capacity was again increased and recycling of ash dam waters introduced. Before this time, coal ash was mixed with lake water and pumped to the ash dam, which drained directly into Wyee Bay via Mannering Bay. Since 1995, water has been removed from the ash dam and recycled back to the power station, where it is mixed with cooling water before being discharged into Wyee Bay. The new procedures were expected to raise selenium concentrations within the ash dam but reduce the amount of suspended and dissolved trace metals reaching the lake.

Figure 31:Current ash dam overflow at Wyee Dam wall into Wyee Creek

Figure 32: Settling ponds of Vales Point Ash Dam before release to Wyee Dam.

Figure 33; Wyee Channel which drains into Wyee Creek.

The Vales Point Ash Dam comprises a series of settling ponds. The northern portions of the ash dam (Ponds 1, 2, 3 and 4A) have been filled to capacity and rehabilitated (capped with imported soils). Ponds 4B, 5A and 5B are located in the south-east portion of the ash dam site and were actively receiving wet-sluiced ash until December 2020 and are currently being progressively rehabilitated (i.e. capped with imported soils). The south-west portion of the dam (Ponds 6 and 7) is currently being ash filled. Ash settles in these upper reaches of the dam and the water is pumped back to the Power Station via ash return water pumps.

Figure 34:Excessive water collecting in Vales Point Ash Dam

Various other solid and liquid wastes are also permitted to be directed to the Ash Dam under the EPL including, ash dam water treatment plant residues, treatment plant discharges, coal mine dewatering discharge and other random refuse. Asbestos Containing Material (ACM) has also been disposed of within the dam.

Toxic metals and increased nutrients

Coal ash dams have come under scrutiny in the USA following ash dam failures in Kingston, TN, and Eden, NC, that contaminated the Emory River[111] and Dan River[112], respectively.

Aside from large spills, coal ash lagoons can cause contamination through leachate discharges into surface waters[113] and the leaching of trace elements from unlined lagoons into groundwater aquifers.[114] Studies suggest that coal ash and its leachates pose a significant risk to aquatic wildlife[115], and trace element concentrations measured from ash dam outfalls are often above drinking water guidelines.[116] Coal ash leachates contain complex mixtures of potential contaminants that migrate through a variety of environmental matrices including water, soil, plant, and animal tissues and likely behave differently in each.[117]

Furthermore, fugitive emission of fine ash particulates from coal-fired power plants and subsequent deposition and resuspension in the surrounding terrestrial environment could expose residents to the ash particles and associated contaminants.[118]

Elevated concentrations of toxic elements in coal ash pose human and ecological health risks upon release to the environment. Despite wide public concerns about water quality and human health risks from catastrophic coal ash spills and chronic leaking of coal ash ponds, coal ash disposal has only been partially regulated, and its impacts on aquatic sediment quality and ecological health have been largely overlooked by regulative authorities.[119]

A review of the nutrient inputs from the Vales Point Ash Dam[120] showed it was a significant source of phosphate, relative to the catchment inputs. Total suspended solids (TSS) is also a problem for the ash dam operators, for which Delta has been in breach of EPL limits 27 times since 2017.

111 *Ruhl L, Vengosh A, Dwyer GS, Hsu-Kim H, & Deonarine A (2010). Environmental impacts of the coal ash spill in Kingston, Tennessee: an 18-month survey. Environmental Science and Technology, 44, 9272–9278. doi: 10.1021/es1026739*

112 *Lemly AD (2015). Damage cost of the Dan River coal ash spill. Environmental Pollution, 197, 55–61. doi: 10.1016/j.envpol.2014.11.027*

113 *Rowe CL, Kinney OM, Fiori AP, & Congdon JD (1996). Oral deformities in tadpoles (Rana catesbeiana) associated with coal ash deposition: effects on grazing ability and growth. Freshwater Biology, 36, 723–730: Ruhl L, Vengosh A, Dwyer GS, Hsu-Kim H, Schwartz G, Romanski A, & Smith SD (2012). The impact of coal combustion residue effluent on water resources: a North Carolina example. Environmental Science & Technology, 46, 12226–12233. doi: 10.1021/es303263x.*

114 *Carlson CL, & Adriano DC (1993). Environmental impacts of coal combustion residues. Journal of Environmental Quality, 22, 227–247. doi: 10.2134/jeq1993.00472425002200020002x.*

115 *Rowe CL, Hopkins WA, & Congdon JD (2002). Ecotoxicological implications of aquatic disposal of coal combustion residues in the United States: a review. Environmental Monit. Assess, 80, 207–276. doi: 10.1023/A:1021127120575: Lemly AD, & Skorupa JP (2012). Wildlife and the coal waste policy debate: proposed rules for coal waste disposal ignore lessons from 45 years of wildlife poisoning. Environmental Science & Technology, 46, 8595–8600. doi: 10.1021/es301467q*

116 *Ruhl et al (2012).Op cit*

117 *Olson, L. H., Misenheimer, J. C., Nelson, C. M., Bradham, K. D., & Richardson, C. J. (2017). Influences of Coal Ash Leachates and Emergent Macrophytes on Water Quality in Wetland Microcosms. Water, air, and soil pollution, 228. https://doi.org/10.1007/s11270-017-3520-4*

118 *Nelson, P. F.; Shah, P.; Strezov, V.; Halliburton, B.; Carras, J. N. Environmental Impacts of Coal Combustion: A Risk Approach to Assessment of Emissions. Fuel 2010, 89, 810–816; Zierold, K. M.; Odoh, C. A Review on Fly Ash from Coal-Fired Power Plants: Chemical Composition, Regulations, and Health Evidence. Rev. Environ. Health 2020, 35, 401–418; Klein, D. H.; Russell, P. Heavy Metals. Fallout around a Power Plant. Environ. Sci. Technol. 1973, 7, 357–358; Sato, K.; Sada, K. Effects of Emissions from a Coal-Fired Power Plant on Surface Soil Trace Element Concentrations. Atmos. Environ., Part A 1992, 26, 325–331; Bhanarkar, A. D.; Gavane, A. G.; Tajne, D. S.; Tamhane, S. M.; Nema, P. Composition and Size Distribution of Particules Emissions from a Coal-Fired Power Plant in India. Fuel 2008, 87, 2095–2101; Schroeder, W. H.; Dobson, M.; Kane, D. M.; Johnson, N. D. Toxic Trace Elements Associated with Airborne Particulate Matter: A Review. JAPCA 1987, 37, 1267–1285.*

119 *Zhen Wang, Ellen A. Cowan, Keith C. Seramur, Gary S. Dwyer, Jessie C. Wilson, Randall Karcher, Stefanie Brachfeld, and Avner Vengosh (2022) Environmental Science & Technology 2022 56 (20), 14723-14733 DOI: 10.1021/acs.est.2c04717*

120 *Hodgson, BR, 2006. Vales Point Power Station Assessment of Causes of Long-term Seagrass Changes in Wyee Bay 1953 to 2004. Report to Delta Electricity by Connell Wagner PPI.*

- In 2017/2018, Sunset twice exceeded Total Suspended Solids (TSS) concentration in the discharge into Wyee Bay.[121]
- In 2018/2019, Sunset exceeded TSS limits eight times in discharge to Wyee Bay.[122]
- In 2019/2020, Sunset exceeded TSS limits 14 times in discharge to Wyee Bay.[123]
- In 2020/21, Sunset exceeded TSS discharge limits three times, and twice exceeded copper and iron discharge limits.[124]
- In 2021/22, Sunset exceeded copper discharge limits twice, and once for iron concentrations in discharge. Sunset was further issued with a warning letter for two windblown coal ash events.[125]

On 16 October 2018, Delta also received a clean-up notice from the EPA over unlawfully dumping asbestos in the ash dam,[126] for which it received two $15,000 penalty notices in 2020.

However, apart from the clean-up notice and these two penalty notices, minimal effective regulatory action has ever been undertaken by the EPA .
The cumulative impacts of these additional inputs together with the elevated temperatures in Wyee Bay have never been assessed by Delta. However, these additional impacts are likely to significantly magnify the thermal pollution impacts on seagrass communities within Wyee Bay.

Contamination of metals and metalloids has been the subject of intense scrutiny culminating in a NSW Upper House Inquiry, which made a number of recommendations that are yet to be fully implemented.

A conditions of Vales Point power stations sale included agreements over the apportionment of liability for decommissioning and rehabilitating the sites. These agreements, which meant the State was responsible for the bulk of the site clean-up, were made after a set of Environmental Site Assessments (ESA) identified significant contamination of both sites attributed to a number of operational sources including the very large coal ash waste dam.

The Vales Point power station operators have retrofitted some new technology and processes to slow the contamination, which has seen reductions in sediment concentrations for a number of metals in Mannering Bay. However, arsenic, cadmium and selenium sediment concentrations remain above recommended ecosystem protection levels.

Environmental Resources Management Australia P/L (ERM) was engaged by NSW Treasury as Site Contamination Environmental Advisor and produced eight Environmental Site Assessments (ESA) consisting of soil, sediment, surface water and groundwater assessments of risks to human health and the environment. All the ESAs undertaken by ERM concluded that the concentrations of metals identified in soil, sediment, surface water and groundwater at the sites were considered likely to represent a potential risk.

For the Vales Point ESA,[127] 19 groundwater monitoring wells were installed around most of the Ash Dam boundary out of 117 for the entire site. Groundwater at the ash dam boundary ranged from fresh to highly saline and highly acidic of pH 3.6. The surface water samples collected from the toe drain reported very high concentrations of arsenic, nickel and selenium in groundwater immediately up gradient of the ash dam toe drain.

- Arsenic was found to a maximum of 184 µg/L, with 12 wells exceeding ANZECC drinking water guidelines down gradient of the ash dam. These concentrations were not considered attributable to background concentrations.
- Copper, a significant toxicant for aquatic life, was a maximum 596 µg/L. Eight wells exceeded the maximum reported background copper concentration by a factor two, most of which down gradient of the Ash Dam.
- Lead was found to a maximum of 231 µg/L, with eight wells exceeded maximum background concentrations (20µg/L), most down gradient of the ash dam.
- Nickel with a maximum of 133 µg/L, with three wells down gradient of the ash dam exceeding

121 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=56015&searchrange=licence&option=noncompliance&range=-POEO%20licence
122 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=58859&searchrange=licence&option=noncompliance&range=-POEO%20licence
123 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=61746&searchrange=licence&option=noncompliance&range=POEO%20licence
124 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=64635&searchrange=licence&option=noncompliance&range=-POEO%20licence
125 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=67531&searchrange=licence&option=noncompliance&range=-POEO%20licence
126 https://app.epa.nsw.gov.au/prpoeoapp/ViewPOEONotice.aspx?DOCID=-1&SYSUID=1&LICID=761
127 ERM- Environmental Resource Management P/L, 2014. Project Symphony - Vales Point Power Station. Stage 2 Environmental Site Assessment. Final.

maximum background concentration (32µg/L).
- Selenium with a maximum of 276 µg/L with concentrations at eight wells on the down gradient of the ash dam exceeded the maximum background concentration (10µg/L) by a factor of two.

Selenium was also found at significantly elevated concentrations within sediments in offsite surface water bodies down-gradient of the Ash Dam in Wyee Bay, Mannering Bay, and Wyee Creek. Concentrations of 8 mg/kg to 26mg/kg, generally increasing from the ash dam down the Creek towards Mannering Bay, were found to represent a potential risk to the environment, based particularly on ecological exposure and ingestion of fish.

The ESA concluded that the long term disposal of coal ash waste in the Ash Dam, which are known sources of metal contaminants, may have contributed to metal impacts in the underlying groundwater". The majority of wells found to have concentrations above background values were down gradient of the Ash Dam, which "appears to be a primary source of arsenic and selenium to groundwater and a secondary source of cobalt, copper, lead, manganese, nickel and zinc".

The groundwater beneath the Ash Dam flows towards Lake Macquarie. Metal contamination of southern Lake Macquarie have been identified by numerous studies.[128] A 1996 NSW health study found mean selenium concentration of the flesh of Lake Macquarie finfish was 1.2 mg/kg (dry weight). Dalton and Bird (2003) conducted a risk assessment for consumption of Lake Macquarie fish species and found an allowable adult consumption of 1.35 kg each week.

Documents obtained by the HCEC in 2020 from the then-NSW Office of Environment and Heritage (OEH) under freedom of information law suggest the selenium risk had not improved over the intervening 24 years. Mud crabs, however, were found to have concentrations above levels that could cause human exposure to cadmium toxicity if consumed more than once a week.[129] The Vales Point ESA did find elevated concentrations of cadmium in sediment of Wyee Bay, but elevated cadmium was not found in groundwater.

The maximum arsenic concentration of the fish flesh was found to be 70 part per million from a Blue Swimmer Crab from the very southern end of Lake Macquarie. Food Standards Australia set a maximum of 1 part per million arsenic for all food sold in Australia.

HCEC collected flesh, organs and shell from two male Blue Swimmer Crabs and one male Mud Crab caught in a dilly trap from the southern end of Wyee Bay in late 2020, and sent them for metal analysis.

- The flesh and organs of the Mud Crab were found to contain significant concentrations of Selenium - 4 ppm and 3 ppm respectively.
- Cadmium was found in the shell and organs, but not the flesh, of all three crabs. The organs contained significantly higher concentrations of cadmium; the Blue Swimmer Crabs 5.3 ppm and 5.7 ppm, and the Mud Crab 9.1 ppm.
- Significant concentrations of arsenic was found in the flesh and organs of all three crabs of between 6 ppm and 9 ppm.

A 2021 consultant's[130] report prepared in response to a complaint by a nearby nursery business contaminated groundwater seepage found all wells closest to the reported groundwater seepage reported metal concentrations (particularly aluminium, copper, lead, and zinc) that were considered sufficiently elevated to suggest possible groundwater impact at these locations, possibly through a process of dissolution of metals from ash/soil caused by acidic groundwater conditions. Similar elevated total metal concentrations were reported at groundwater seepage discharge points and the Ash Dam Pipe.

The Vales Point Ash Dam has been an operational ash repository for over 60 years, and during this time ash has been wet-sluiced using saline waters from Lake

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128 *Roach, A.C., 2005. Assessment of metals in sediments from Lake Macquarie, New South Wales, Australia, using normalisation models and sediment quality guidelines. Marine Environmental Research, Volume 59, Issue 5, June 2005, Pages 453-472; Roach, A.C., Maher, W. & Krikowa, F. 2008. Assessment of Metals in Fish from Lake Macquarie, New South Wales, Australia. Arch Environ Contam Toxicol (2008) 54: 292. https://doi.org/10.1007/s00244- 007-9027-z Roberts, B.,1994, The accumulation and distribution of selenium in fish from Lake Macquarie, NSW, Honours thesis, Faculty of Applied Sciences, University of Canberra. Roach, A.C., 2005. Assessment of metals in sediments from Lake Macquarie, New South Wales, Australia, using normalisation models and sediment quality guidelines. Marine Environmental Research, Volume 59, Issue 5, June 2005, Pages 453-472 Roach, A.C., Maher, W. & Krikowa, F. 2008. Assessment of Metals in Fish from Lake Macquarie, New South Wales, Australia. Arch Environ Contam Toxicol. 54: 292. https://doi.org/10.1007/s00244-007- 9027-z*

129 *OEH – NSW Office of Environment and Heritage, EPS Branch, 2019. Contaminates and risk assessment and advice for metal concentrations in seafood from Lake Macquarie, NSW June 2018. DOC18/421445*

130 *Douglas Partners, 2021. Report on Groundwater Assessment In the Vicinity of Lot 421 in DP 578194, Doyalson North for Delta Electricity, Accessed under NSW Parliamentary Standing Orders 52.*

Macquarie for transporting the ash along pipelines to the Dam.

The consultant's report suggests "it is likely that over this time the ash in the Dam have experienced anaerobic conditions resulting in sulfate-reducing bacteria in the ash converting dissolved sulfate present in the pore water to react with metals, particularly iron, resulting in the formation of metal sulphides (principally pyrite). It is likely that wet-sluicing of the ash for disposal has resulted in RIS oxidation, and the resultant lowering of groundwater pH and the dissolution of trace metals and metalloids. Groundwaters and surface water affected by RIS oxidation can be characterised as highly saline, low pH and have elevated metal concentrations."

The report recommended ceasing wet-sluicing of ash as soon as possible and the investigation of preferential groundwater migration pathways noting that it is likely that one exists through fractures, joints and/or bedding planes in the weathered Munmorah Conglomerate rock.

Ash transport

Flyash is collected from the stacks at Vales Point Power Station and stored in the ash dam immediately south of Mannering Bay where the ash is settled out and the water discharged to the cooling water outlet canal, which directs flows to the southern end of Wyee Bay. Since 1996, only excess water from the ash dam, which is mostly due to catchment rainfall runoff, overflows to Wyee Creek before entering Wyee Bay. Treated sewage from the power station is placed with ash in the ash dam.

Coal ash is transported from the power station to the ash dam by wet sluicing via pipelines, where the ash is settled-out and the saline water is returned to the power station. It is understood that this method of transport/disposal has been used since the ash dam was constructed in 1962.

Due to the inherent risk associated with adding additional water to the ash dam and the risk of groundwater contamination, Vales Point is perhaps the only power stations in Australia still using wet sluicing ash transport, which agitates the ash pumped from boilers to the ash dump in a slurry of over 90 percent water. Installing dense phase ash transport technology, which uses only 30 percent water, would significantly reduce metal concentrations in leachate that enters Lake Macquarie.

Since about 1990, most coal-fired power stations in the world use dense or lean phase ash transport which used up to 10% water. In 1987, The Electricity Commission of New South Wales constructed a pilot dense phase fly ash slurry system at Vales Point Power Station.[131] The dense phase ash slurry was to be pumped 1737 meters to a disposal site at the power station ash dam. The original design concept of the dense phase ash slurry plant was that the plant would pump a dense phase paste. The major design criterion was the pipeline pressure drop (ΔP). Data obtained from Verkerk (1986) was used in sizing the pipeline. The tender specified a pump with a theoretical volumetric flow-rate of 30m^3 h-1 at 9.0 MPa. Approximately 9,300 tonnes of dense phase fly ash slurry was transferred to the disposal site without incident.

The installation of new dense phase ash transport infrastructure designed to reduce the water collecting in the ash dam is essential in reducing groundwater contamination, and the continual contamination of Lake Macquarie with metals and metalloids.

131 *Bunn T. F. and Chambers A. J., (1991), "Characterisation of Fly Ash Slurries", International Mechanical Engineering Congress, Sydney, NSW, Australia, 8 - 12 July, pp. 50 - 61.*

Vales Point Environmental Protection Licence breaches

Since the sale of Vales Point to Sunset Power International, Environmental Protection Licence (EPL) breaches began to occur more frequently.
The 2016 EPA Compliance Report for the Vales Point Ash Dam[132] found that Delta was not complying with conditions of its EPL 761 and the legislative requirements in relation to the scope of the audit. These non-compliances included:

- Water levels in the dam were not being managed efficiently so as to minimise or prevent the pollution of surface waters.
- Secondary containment and/or other management system was not in place for the return water tank.
- Some plant and equipment was not being maintained in a proper and efficient condition.
- Approved methods for analysing water samples were not being used by the licensee's laboratory.
- A pH sample exceeded the specified range.
- Not all required information was contained in the licensee's Pollution Incident Response Management Plan (PIRMP).

However, the Compliance Report appears to have had little effect on Delta's environmental compliance. For example:

- On 16 October 2018, Sunset received a clean-up notice from the EPA over unlawfully dumping asbestos in the ash dam.[133] On 16 Sep 2020, Sunset received two $15,000 penalty notices for the asbestos dumping.
- In 2017/2018, Sunset twice exceeded Total Suspended Solids (TSS) concentration in the discharge into Wyee Bay.[134]
- In 2018/2019, Sunset exceeded TSS limits eight times in discharge to Wyee Bay.[135]
- In 2019/2020, Sunset exceeded TSS limits 14 times in discharge to Wyee Bay.[136]
- In 2020/21, Sunset exceeded TSS discharge limits three times, and twice exceeded copper and iron discharge limits.[137]
- In 2020/21, Sunset exceeded copper discharge limits twice, and once for iron concentrations in discharge. Sunset was further issued with a warning letter for two windblown coal ash events.[138]

Delta's environmental performance is sloppy. Numerous emails from EPA to Delta (accessed under freedom of information laws) reveal concerns over the number of compliance and reporting breaches. The NSW EPA must take its responsibility to the community and environment of Lake Macquarie much more seriously. Mechanisms are in place to force Delta Electricity to reduce its impacts. However, to date the EPA has been reluctant to prosecute Delta for any of its many EPL breaches, and has instead relied on Infringement notices and public shaming. These processes have clearly not worked and have led to the continual environmental degradation of Lake Macquarie by this privately owned facility.

In the competitive electricity market of the NEM, such advantages provided to Delta can be seen as an informal subsidy putting cleaner forms of energy production at a decisive competitive disadvantage.

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132 EPA, 2016. Compliance Audit Program: Coal Ash Dams Final Compliance Audit Report Vales Point Power Station and Coal Unloader EPL 761 Vales Point Road Mannering Park NSW 2259 August 2016. A

133 https://app.epa.nsw.gov.au/prpoeoapp/ViewPOEONotice.aspx?DOCID=-1&SYSUID=1&LICID=761

134 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=56015&searchrange=licence&option=noncompliance&range=-POEO%20licence

135 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=58859&searchrange=licence&option=noncompliance&range=-POEO%20licence

136 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=61746&searchrange=licence&option=noncompliance&range=POEO%20licence

137 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=64635&searchrange=licence&option=noncompliance&range=-POEO%20licence

138 https://app.epa.nsw.gov.au/prpoeoapp/Detail.aspx?id=761&periodid=67531&searchrange=licence&option=noncompliance&range=-POEO%20licence

Chain Valley and Mannering coal mines

To supply coal for the Vales Point power station, underground mining by the Chain Valley and Mannering mines began operating in 1962. Utilising board and pillar mining and since 2010 miniwall methods within the Fassifern, Great Northern and Waratah coal seams to between 150 and 200m below ground level. [139]

All coal produced is transported by conveyor from the Mannering Colliery to Vales Point power station. The mines are owned by Sunset Power International Pty Ltd, and the mines formed an essential part of the sale of Delta Electricity to Sev.en Global Investments Pty Ltd. A current application to continue mining until 2029 is being assessed.[140]The consent for these mines expires in 2027. Without these mines Vales Point would have to source coal from elsewhere at market rates.

The presence of underground coal mining has defined the development and urban regeneration of the area. The form of settlements and their location aboveground has been mediated by the presence of underground mine shafts and the cost of grouting them.[141] However, little inquiry is evident into the subsidence impacts caused by coal mining to the lakebed of Lake Macquarie.

Delta Coal can currently extract and transport up to 3.2 million tonnes per annum of run-of-mine coal from the Chain Valley Colliery and Mannering Colliery until December 31, 2027. While the Consolidation Project proposes increasing the area mined, it will reduce annual coal extraction to 2.8 million tonnes of run-of-mine coal. We estimate the annual coal consumption of the Vales Point power station, owned by Delta Coal's parent company Sunset Power International Pty Ltd, is about 2.65 million tonnes - at a plant load factor of 63.75% (7,372 GW·h/pa).

It appears that Delta Coals EPL compliance is even sloppier than its parent Delta Electricity. The POEO Register reveals that Delta Coal has only been compliant in six of the past 22 years, with 23 individual breaches since Delta Coal took over operations in 2019. Delta Coal's operations appears to be in chronic breach of EPLs. Exceedances of discharge volumes, faecal coliforms, TSS, and oil and grease concentrations are consistently breached multiple times in some years.

The continuation of coal mining to 2029 will be made possible by secondary extraction below Lake Macquarie, which entails mining the support pillars left after past mining operations. The maximum predicted subsidence of the Lake bed due to this secondary extraction is 780mm. However, this is in addition to the subsidence that has already been experienced, which appears to be up to 1.2m.

Mining has occurred beneath much of the Vales Point Ash Dam and surrounds, and is likely to be contributing to groundwater contamination through fractures in the goaf above the top of the mined pannels and the bottom of the Ash Dam.

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139 *https://miningdataonline.com/property/314/Chain-Valley-Mine.aspx*

140 *See https://www.planningportal.nsw.gov.au/major-projects/projects/chain-valley-colliery-consolidation-project*

141 *Lois C Towart, Kristian Ruming, Pauline McGuirk, Kathy Mee, 2019. What lies beneath? Exploring the material influence of the underground on urban development in Newcastle and Lake Macquarie. State of Australian Cities Conference and PhD Symposium 30th November - 5th December, 2019 Perth, Western Australia. https://apo.org.au/sites/default/files/resource-files/2019-12/apo-nid303876.pdf*

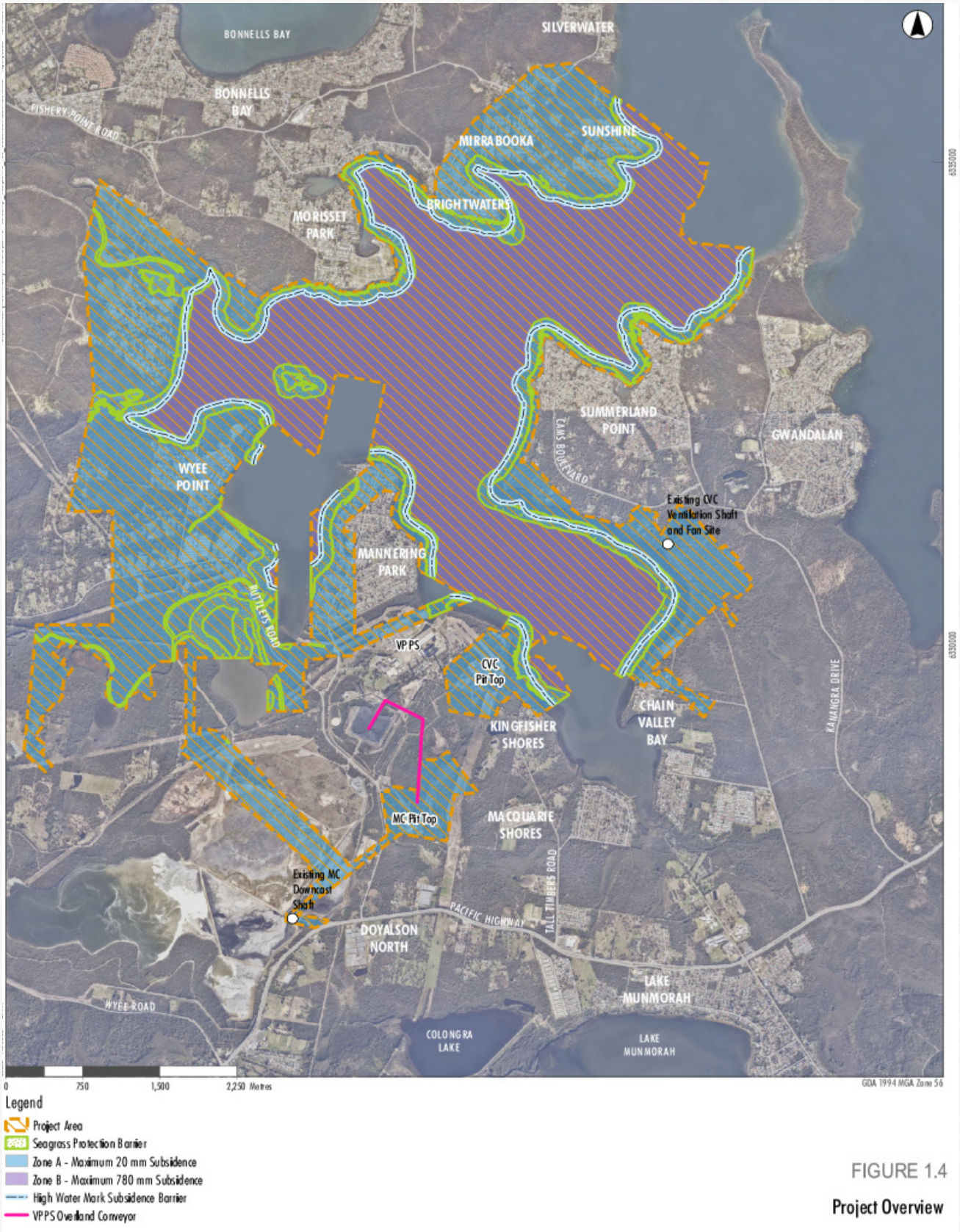

Figure 34: Chain Valley and Mannering coal mine workings showing mining beneath the Vales Point Ash Dam

Subsidence associated with underground coal mining in the area has caused obvious significant damage to buildings and the terrestrial environment. Unplanned subsidence in 1987 affected the townships of Chain Valley Bay South and Chain Valley Bay North (Teragalin Drive and Foreshore) associated with mining that involved pillar extraction within the Great Northern Seam at Newvale Colliery.

Subsidence impacts to surface infrastructure and natural features were significant. The subsidence apparently ruined the wetland and damaged homes and infrastructure.[142] Previous coal mining damage at Chain Valley Bay includes subsidence of Karignan Creek causing a rise in water level, killing thousands of native trees.[143]

The Biodiversity Assessment for the EIS prepared for the Chain Valley Colliery Consolidation Project application (SSD-17017460)[144] points to annual seagrass surveys since 2020 having "discovered large and unexplained changes in seagrass cover". The Assessment suggests this is unrelated to underground coal mining, as mining had not impacted seagrass beds since commencement of monitoring. This adds nothing to our understanding of likely cumulative impacts to seagrass beds and possible disturbance to the complex relationships between and within benthic communities, which may be disrupted by the Project.

Seagrasses are flowering plants that photosynthesise, making them sensitive to mine subsidence. Subsidence lowers the lakebed and reduces the amount of light penetration as it increases the water depth. Nutrient input and turbidity of the Lake have compounding effects. Benthic (bottom) communities such as seagrass beds are key to the survival of juvenile fishes due to the refuge they provide from predators.[145] Subsidence can affect benthic communities by increasing the depth of the lakebed and decreasing the light penetration of the water column.[146] It also affects light dependent biota, such as algae and biofilms, on which benthic organisms such as molluscs, annelid worms, and crustaceans feed.[147]

The EIS points to the "Seagrass Protection Barrier (SPB)" as protecting seagrass from subsidence, which together with the "High Water Mark Subsidence Barrier (HWMSB)" forms Zone A suggested to be subject of a maximum of 20 mm subsidence, rather than the maximum 780 mm for Zone B, which is beneath the deeper water of southern Lake Macquarie. However, an assessment of the relationships between the extent of seagrass, subsidence, and potential cumulative impacts of operating Vales Point power station and the Collieries operated by Delta Coal, is lacking.

Lake water is drawn into the Vales Point power station to operate the cooling-water condensers via an intake canal on the western shore of Chain Valley Bay. The cooling water is returned to the lake via an open canal at a point close to the southern-most end and on the eastern shore of Wyee Bay at a maximum temperatures of 35°C and a mean flow of 4.32 GL a day.[148] The maximum EPL discharge volume is set at 6.5GL/day. Such flow has considerable impact on water temperatures and turbidity outside of Wyee Bay.

Seagrass in Wyee Bay has all but disappeared due to excessive thermal pollution from the Vales Point power station. Increased water temperatures and flow from Vales Point's discharge has been shown to influence temperatures at the Vales Point intakes in Chain Valley Bay. However, no assessment is evident in the EIS to determine whether this increased temperatures is affecting seagrass beds in Chain Valley Bay, or indeed having a cumulative effect on seagrasses.

The Vales Point power station is the potential cause of significant turbidity, which is often high in the waters of southern Lake Macquarie. Yet the EIS does not explore these interaction and potential cumulative impacts of lower light availability and subsidence, and whether this has any appreciable impact on the extant area of seagrass, or whether an accumulation of stressors, including turbidity thermal pollution, hypo-salinity, and subsidence could be impacting seagrass beds.

Indeed, no assessment is provided in the EIS of the potential impact on Lake Macquarie from the proponent's own discharge. The 2013, Assessment Report for Chain Valley Colliery Modification to Mining Extension 1 (SSD 5465 Mod 2) states the median annual groundwater inflow to the Fassifern Seam workings at Chain Valley was 2,440 mega lites (ML) and was predicted to increase to 3,832 ML. The volume licenced is 4,443 ML/yr.

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142 *https://www.newcastleherald.com.au/story/446425/lake-macquarie-map-shows-massive-coal-deposits/*
143 *ibid*
144 *https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-17017460%212022092 8T105738.648%20GMT*
145 *Jelbart JE, Ross PM and Connolly RM (2007) Patterns of small fish distributions in seagrass beds in a temperate Australian estuary. Journal of the Marine Biology Association UK 87, 1297-1307.*
146 *ibid*
147 *ibid*
148 *Ingleton & McMinn (2012). Op cit*

Total groundwater inflows to mine between 2018 and 2022 averaged 6.7 ML/day (2,445 ML/pa). However, total groundwater inflow in 2019 was 3,129 ML. On an annual basis, average groundwater inflow to the Fassifern Seam increased from 0.5 ML/day in 2019 to 1.4 ML/day in 2020, which may be attributable to secondary extraction.

The EIS for the Chain Valley Colliery Consolidation Project currently under assessment states that groundwater inflow is brackish to saline in subsided areas of the Great Northern Seam workings (11,800–28,200 mg/L). However, seepage from a dyke at the northern end of the current Fassifern Seam workings was reported to have brackish salinity (2,390 mg/L) and a pH of 8.63, indicating an absence of hydraulic connection between Lake Macquarie and the Fassifern Seam. Indeed, EPL monitoring by Delta Coal shows some discharge with very low salinity. For example, 7 July 2022 EPL monitoring results show discharge of 2.4ML with an EC of 302 us/cm (142 mg/L salinity). A level that may cause seagrass beds to die-back.

Figure 35: CVC pit mouth, discharge settlement ponds, and Swindles Creek mine discharge.

Seagrasses are seasonally exposed to low salinity events during catchment runoff which exposes them to osmotic shock. Halophila ovalis and Zostera muelleri has been demonstrated to show stress responses to salinity ranging from 3 to 36 PSU (~103 mg/L -1,224 mg/L at 25°C).[149] Optimum salinity was found by Collier et al (2014) to be above 36 PSU (1,224 mg/L at 25°C) with osmotic stress appearing as small increases in shoot density at 27–33 PSU (~920 mg/L -1130 mg/L at 25°C). Zostera muelleri was found to survive to salinities as low as 3 PSU (102.6mg/L at 25°C), while Halophila ovalis remained abundant at 9 PSU (308 mg/L at 25°C).

The study demonstrates that seed production in these species was inhibited by chronic exposure to hypo-salinity. These authors point out that even If seed production and germination is successful, seedling development is highly sensitive to small changes in salinity. Increased shoot density of Zostera and Halophila in response to severe osmotic shock could suggest that the population is healthy and increasing in abundance, while in fact is under significant stress and unable to sexually reproduce.

Seagrass in Chain Valley Bay appears to be regularly exposed to unnatural hypo-saline conditions resulting from the discharge of Delta Coal's groundwater inflow. Such salinity levels as low as 142 mg/L has been shown to cause seagrass die-off.

The EPL only imposes limits on concentrations of faecal coliforms, pH, and TSS in the discharge. While the EPLs imposes a requirement for Delta Coal to monitor for many toxicants, the limit of reporting (LOR) of some results make them unusable for assessing impacts. The EPL for Vales Point power station discharge must be below 5 ppb selenium, however, Delta Coal's EPL monitoring results do not report for selenium less than 10ppb.

Nevertheless, a scan of Delta Coal's EPL monitoring results of the past 12 months shows concentrations of copper 3 ppb (February 2022) and silver 4ppb (May 2022), all above ANZECC 2000 Guideline values for marine waters (95%).

While the EPLs require monitoring of TSS, they fail to require monitoring for turbidity (ANZECC 2000 Trigger Value 0.5–10 NTU) or light attenuation which would be far more useful in identifying likely impacts on seagrass.

149 *Collier, Catherine & Villacorta-Rath, Cecilia & Dijk, Kor-jent & Takahashi, Miwa & Waycott, Michelle. (2014). Seagrass Proliferation Precedes Mortality during Hypo-Salinity Events: A Stress-Induced Morphometric Response. PloS one. 9. e94014. 10.1371/journal.pone.0094014.*

Conclusion

Vales Point power station and the mines that supply its coal have operated on the shores of Lake Macquarie for the past 60 years. Over that time these operations have been shown to be poor neighbours to the half a million people now residing in the cities of Lake Macquarie and Central Coast. Over the time these facilities have operated the climate has also changed due in large part to the mining and burning of coal.

However, since the sale of these once publically owned asset, Delta appears to have been in chronic breach of Environmental Licence conditions. Water levels in the 500 ha ash dam have not been managed properly to effectively minimise or prevent the pollution of groundwater and Lake Macquarie, and plant and equipment has not being maintained in a proper and efficient condition so as to minimise its impacts. The power station and coal mining operations Delta owns have been responsible for 57 Licence breaches relating to the pollution of Lake Macquarie, as well as for 2 breaches for asbestos dumping, and 2 for potentially toxic coal ash blowing onto neighbours.

However, apart two penalty notices issued for $15,000, little or no effective regulatory action has ever been undertaken by the EPA.

Fugitive emission of fine ash particulates from coal-fired power plants and subsequent deposition and resuspension in the surrounding terrestrial environment has been shown to expose residents and the environment to coal ash particles and associated contaminants. Despite a significant body of evidence showing the impact of such pollution, it has seen little attention from regulators.

To date the EPA has been reluctant to prosecute Delta for any of it many EPL breaches, and has instead relied on penalty notices and public shaming. These processes have clearly not worked and have led to the continual degradation of Lake Macquarie by these privately owned facilities. Due to the tight electricity market, the company now seems to believe it is immune from prosecution, and continues to pursue profit over compliance with the laws of NSW. The EPA, tasked with protecting the surrounding population and environment from such corporate avarice, has revealed itself to be weak and ineffective.

The Vales Point power station pumps twice the equivalent volume of water from Lake Macquarie every year and probably four times the volume of southern Lake Macquarie. Such a massive intake of water is likely to result in a significant decrease in fish and marine life of the Lake. Many large fish and marine turtles are killed at the intake screens, and most or all of the fish larvae and plankton taken through the power station are likely killed, severely reducing the ecological productivity of southern Lake Macquarie.

When this massive volume of water is released back into the Lake it has been treated with chlorine and other chemicals and heated by about 10^{0}C, killing or damaging the seagrass with about 2 km from the outlet. The power station's thermal pollution has been discharged up to 11.3^{0}C above average ambient Lake temperatures in winter and 15.7^{0}C above average ambient temperatures in summer. We don't believe that any power station built anywhere in the world today would be approved to discharge thermal pollution at such temperature differentials.

Thermal power stations elsewhere in the world are required to limit the temperature differential of discharged cooling water to between 3 and 5^{0}C. However, even after clear evidence of ecological damage to the Lake, and its causes, the EPA has approved three temperature increases since 2005 that has allow the company to discharge hot water to 38.5^{0}C so as to maximise profits when electricity demand is highest.

In light of the EPA's failure, which contributed to the disappearance of seagrass under such flexible Licencing conditions, the EPL reduced the number of hours that the power station could discharge water at such temperature in 2021. However, discharge temperatures and the damage it has caused has not been fully rectified. Evidence provided by Delta, as well as numerous Government and third party

reports, suggests summer discharge temperatures remain far too high, and the discharge temperatures in winter have yet to receive any regulatory attention.

Compelling evidence, including DPI Fisheries seagrass mapping released in 2001, 2008, and 2012, suggests about 55 ha of seagrass has been lost due to Delta's excessive thermal pollution which was first increased from the design temperature of 35^{0}C to 37.5^{0}C in 2005. We believe that seagrass recovery will not be evident until the maximum discharge temperatures in summer and winter are reduced considerably.

Seagrass in south eastern Australia have been calculated to enhances commercial fishery production by $230 000 ha a year. According to these figures, the loss of almost 55ha of seagrass from Wyee Bay since 2008 equates to about $12.6M a year of lost commercial fishery production, and over the period 2005 to 2023 commercial fisheries of south eastern Australia has suffered a combined loss of about $226.8M.

Compounding the effects of thermal pollution on Lake Macquarie is contamination of nutrients, metals, metalloids, and turbidity from the Vales Point ash dam and coal mines. Numerous reports have shown that the ash dam is a significant source of phosphate, and Delta Electricity and Delta Coal have breached EPL limits for Total Suspended Solids (TSS) almost 50 times since taking ownership. The cumulative impacts of these additional inputs together with the elevated temperatures have never been assessed. However, these inputs are likely to significantly magnify impacts.

Coal ash dams have come under scrutiny since several massive ash spills in the USA. Aside from the potential for an ash spill into Lake Macquarie, unlined coal ash lagoons, such as that of Vales Point, cause contamination through discharges into surface waters and migration of trace elements to groundwater. Elevated concentrations of toxic elements in sediments of southern Lake Macquarie have received significant public attention. However, despite a NSW Parliamentary Inquiry into ash dams in NSW, the chronic leaking of toxins from Vales Point ash dam has been largely overlooked by regulative authorities.

While the ash dam stores between 60 and 100 million tonnes of coal ash, which itself poses a significant risk to Lake Macquarie, it also holds far too much water, which mobilises toxins within the ash. Elsewhere in Australia and the world, coal ash is transported to storage facilities using far less water than used by Vales Point. The installation of new dense phase ash transport infrastructure designed to reduce the water collecting in the ash dam is essential in reducing groundwater contamination, and the continual contamination of Lake Macquarie with metals and metalloids.

Combined with elevated temperatures, nutrients, turbidity, and toxins for which the power station and coal mines are responsible, is the additional risk of up to 1,200kg of chlorine which is added to the power station cooling water. There appears to be a regulatory disconnect between the chlorine treatment used by Delta, the free chlorine concentration limit discharge into Wyee Bay, and the chlorine concentration limit that would protect marine species.

Despite peak chlorine concentrations at the hot water outlet generally remaining under regulatory limits, it is well above both National Water Quality Guidelines, and levels that have been shown to cause impacts on marine life.

The second mass death of fish in Wyee Bay in September 2022 has sparked an as yet unresolved EPA criminal investigation, which included the securing of power station equipment. The fish kill appeared to HCEC staff and Mannering Park residents to be concentrated nearest to the hot water outlet and may well be related to its discharge.

The Vales Point power station and its coal mines have recently been purchased by a new private company, who has shown itself to give scant regard to the communities and environment in which it operates in Europe. The new owner has indicated its intention to operate beyond the design life of the power station in 2029.

The HCEC is not alone in believing that much of the pollution from the power station and mines is the result of a desire by the former owner to save on the costs of essential maintenance and upgrades. The community and environment of Lake Macquarie are suffering as a result of these cost savings and the company must be forced to update the facility. The new owner must be forced to cough up the required costs associated with reducing its impacts and the EPA must be provided with the political will, as well as adequate funding, to ensure these upgrades are made.

Recommendations

1. To encourage the rejuvenation of Zostera seagrass within Wyee Bay, a study be undertaken that determines ambient water quality, appropriate seasonal temperature differentials, seagrass sensitivity, and the assimilative capacity of Wyee Bay, and EPL 761 be varied accordingly to incorporate a scientifically established thermal mixing zone south of Wyee Marina.

2. To offset seagrass loss in Myuna and Wyee Bays, a Lake Macquarie Seagrass Trust be established with funding of $12M a year from Delta Electricity and $8M a year from Origin Energy to enhance seagrass meadows within Lake Macquarie and replace seagrass damaged and killed by the operations of Vales Point and Eraring power stations.

3. A Pollution Reduction Program be established to reduce the amount of chlorine discharged into Wyee Bay, and to force Delta Electricity to upgrade its procedures for reducing biofouling of condensers and pumps.

4. After appropriate trials and engineering design, to minimise toxic trace elements contained within Vales Point coal ash from mobilising and entering groundwater and Lake Macquarie, EPL 761 be varied to incorporate a clause that directs Delta Electricity to install new plant and machinery for dense phase ash transport to the Vales Point Ash Dam.

5. A cumulative impact study be undertaken under a variation to EPL 761, EPL 191 (Mannering Colliery), and EPL 1170 (Chain Valley Colliery) to establish a Pollution Reduction Program for Total Suspended Solids (TSS), faecal coliforms, oil and grease, and metals and metalloids, and to determine the interaction of mine subsidence, the undermining of Vales Point ash dam, and their impacts on marine life in Wyee and Chain Valley Bays.

6. The NSW Environmental Protection Authority (EPA) be adequately funded to ensure appropriate oversight and regulation of large corporate polluters, and enhance its ability to prosecute polluters.

7. The $15,000 the EPA can issue under Penalty Notices be increased to $150,000.

Appendix 1. Vales Point Discharge temperatures 2013-2023.

Delta Electricity Environmental Licences and Monitoring. Vales Point Power Station Monthly Environmental Data Summary; Point 22. Discharge of cooling water from the cooling water outlet canal to Wyee Bay. https://www.de.com.au/environment/environmental-licences-and-monitoring

Red - >37.5°C

Green - >35°C

Published Date	Min. Value	Mean Value	Max. Value
Jun-13	22.5	26.4	28.7
Jul-13	24.2	25.6	27.5
Aug-13	22.5	24.9	28.3
Sep-13	25.7	28.7	31.2
Oct-13	28.4	30.7	33
Nov-13	29.7	31.7	33.4
Dec-13	**30.3**	**33.2**	**37**
Jan-14	**31.1**	**33.3**	**35.8**
Feb-14	31.3	33.3	35.3
Mar-14	31.2	32.9	34.9
Apr-14	29.3	31.5	33.5
May-14	27.8	29.1	31.1
Jun-14	25.7	27.4	28.8
Jul-14	18.4	21.6	25.8
Aug-14	16.7	23.2	26.8
Sep-14	15.7	23.1	30.5
Oct-14	27.3	30.5	34
Nov-14	**29.7**	**33**	**36.2**
Dec-14	29.7	33.4	35
Jan-15	30.4	33	34.7
Feb-15	**32.2**	**34.2**	**35.8**
Mar-15	32.5	33.5	34.8
Apr-15	29.6	31.9	34.1
May-15	27.3	29.9	32.4
Jun-15	24.4	27.7	32
Jul-15	21.5	24.8	26.2
Aug-15	25	26.3	28.1
Sep-15	22.7	28.1	30.5
Oct-15	29.4	32.4	34
Nov-15	31.2	33.2	33.9
Dec-15	31	32.7	33.7
Jan-16	**30.4**	**34.2**	**36.5**
Feb-16	**31.5**	**34.2**	**36.4**
Mar-16	**33.6**	**34.8**	**36.6**
Apr-16	**29**	**32.7**	**35.6**
May-16	24.2	31.7	33.9
Jun-16	18.6	25.2	29.9
Jul-16	16.3	22.7	27
Aug-16	19	24.9	28.4
Sep-16	20.9	26.7	30.5
Oct-16	20.7	28.8	32.1
Nov-16	27.9	32.4	34.2
Dec-16	**27.8**	**32.7**	**35.95**
Jan-17	**31.6**	**33.7**	**36.6**
Feb-17	**30.9**	**33.9**	**38.1**
Mar-17	27.7	32.3	34.7
Apr-17	24.8	30.5	33.7
May-17	23.7	28.3	32.2
Jun-17	22	25.5	28.4
Jul-17	20.2	24.4	27.3
Aug-17	19.6	24.4	26.8
Sep-17	22.3	26.5	30.9
Oct-17	25.9	30.8	34
Nov-17	26.1	31.5	34.4
Dec-17	**29.7**	**33.1**	**36.7**
Jan-18	**29.6**	**33.4**	**36.4**
Feb-18	28.6	32.6	36
Mar-18	27.1	32.2	34.9
Apr-18	24.2	30.3	33.6
May-18	21.6	27	32
Jun-18	20.2	25.2	28.1

Jul-18	20.2	24	27.2
Aug-18	20	24.5	26.6
Sep-18	**32**	**34.8**	**38.1**
Oct-18	**29.6**	**33.7**	**36.7**
Nov-18	29.1	32.8	34.9
Dec-18	25.4	31	34
Jan-19	23.2	28.4	31.6
Feb-19	21.1	24.9	27.8
Mar-19	29.1	32.8	34.9
Apr-19	25.4	31	34
May-19	23.2	28.4	31.6
Jun-19	21.1	24.9	27.8
Jul-19	18.5	23.6	27.5
Aug-19	18.6	23.7	27
Sep-19	17.3	25.3	29.4
Oct-19	24.4	29.6	34.3
Nov-19	28.7	31	33.8
Dec-19	26.3	30.8	34.9
Jan-20	**29.4**	**32.8**	**37.8**
Feb-20	**26.9**	**32.4**	**38.1**
Mar-20	25	30.7	34.7
Apr-20	23.4	27.7	32.2
May-20	17.7	26.1	32.3
Jun-20	15.7	23.7	30.2
Jul-20			
Aug-20	18.8	24.3	29.2
Sep-20	19.3	26	32.9
Oct-20	24	29.2	31.8
Nov-20	26.1	31	34.8
Dec-20	25.7	30.9	34.1
Jan-21	**28**	**31.5**	**35.7**
Feb-21	27.2	30.7	33.8
Mar-21	25.04	29.97	34
Apr-21	19.9	28.2	31.6
May-21	21.1	28.2	35.1
Jun-21	17.9	23.2	28.6
Jul-21	18.3	22.6	25.7
Aug-21	18.1	21.6	24.7
Sep-21	19.8	23.1	28.1
Oct-21	21.7	25.8	30.3
Nov-21	23.7	27.1	32.2
Dec-21	23.7	28.7	35
Jan-22	**25.8**	**31.5**	**36.7**
Feb-22	**26.8**	**30.5**	**36.3**
Mar-22	26.7	29.6	34.3
Apr-22	24	30.1	33.9
May-22	22.7	27.4	32.2
Jun-22	18.1	22.4	26.5
Jul-22	18.9	23.4	26.8
Aug-22	19.9	24.3	28.6
Sep-22	20	24.8	30
Oct-22	22.4	27.9	33
Nov-22	23.5	29.7	33.4
Dec-22	25.3	30.1	33.8
Jan-23	**26.8**	**31.3**	**36.2**
Feb-23	**29.7**	**32.1**	**35.9**
Mar-23	28.6	31.5	34.5

Hunter Community
Environment Centre